NBS in Vulnerable Geographies

Applicability of NBS in socio-economic unequal urban/peri-urban contexts with water-related challenges

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NBS in Vulnerable Geographies

Applicability of NBS in socio-economic unequal urban/peri-urban contexts with water-related challenges

Community-led restoration of Nong Pung Urban River. Chiang Rai, Thailand

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1. Introduction

To achieve inclusive and sustainable urban development, the introduction of water related Nature Based Solutions (NBS) have proven to be effective in specific urban contexts. Different sources point out their contribution to various SDG's in Europe, Australia and the United States, all of which are regions with high GDP levels with strong institutional contexts. However, in regions that are underdeveloped, have weak institutional contexts, high social and economic inequality and are situated in more vulnerable or extreme landscapes, the so called '*vulnerable geographies*', the experience with Nature Based Solutions is less extensive (PBL, 2018). This report presents the results of a literature review that aims at providing a first (broad) exploration of NBS in contexts outside the regions mentioned above, casting light into the following question:

Which types of interventions, reacting to which types of water problems (systemic or local) and which capital, stakeholders, institutions and financial structures are appropriate in vulnerable geographies in extreme landscapes?

This study introduces the term 'vulnerable geographies' in which geographies are understood as both the human system (governance, socio-economic situation) and the environment (natural system, climate) as an acknowledged reciprocal relation. The notion of 'extreme landscapes' is defined as urbanizing landscapes under extreme climatic conditions. More specifically this research will focus on too much (riverine, coastal and deltaic floods), too little and too polluted following the typology of main water challenges developed in the publication the geography of future water challenges (PBL, 2018).

This research on NBS in vulnerable geograpies stands on the research the geography of future challenges (PBL, 2018) and Future Sustainable Pathways (FSPs) for Cities (Sušnik & Veerbeek, 2020) in which four types of urban settlements are identified according to the main type of water-related challenges they face:

• *Drylands cities*; referring to urban areas located in environments with a relative lack of access to water resources and or high evapotranspiration rates, facing water shortages and insecurity.
• *Riverine cities*; referring to urban areas facing riverine flooding.
• *Coastal cities*; referring to urban areas facing sea flood hazards such as sea level rise, storm surges and tides.
• *Delta cities*; referring to urban areas prone to flood hazards both from the sea and rivers.
• *Other cities*, referring to urban areas that are away from shorelines and rivers, are located in humid environments and therefore facing waterlogging.

In figure 1, the line defining the regions where the mean annual temperature is above 30 is a simplification of the projections made by PBL (2021) and based on a report named "Future of the human climate niche" (Xu C., et al., 2020).

Figure 1
Research orientation
Source: TU Delft

Legend

• Tropical climate
• Subtropical climate
• Arid climate
• Temperatures > 30
• Too much
• Too polluted
• Too little

The research outcome gives a first idea of how to frame the water problem in the specific context of 'vulnerable geographies', the type of solutions and ways of implementation, and a reflection on the co-benefits these NBS have in terms of SDG terms.

This literature study is part of a larger PBL program for the Dutch Ministry of Foreign Affairs that aims to increase the knowledge on strategies on integrated planning and management and their potential to contribute to solving complex nexus challenges. The program also aims to find synergies between the various initiatives that are being funded and developed by the Dutch government worldwide.
The outcomes from this study will:

• Inform the PBL project IWC-II: Water Climate and Adaptation - Pathways of Sustainable Solutions.
• Contribute to the general knowledge of local variations in the effectiveness of water related nature based solutions.
• Inform local, district and regional planners and policymakers, representatives of urban and rural stakeholders -public, private, customary and social organizations- and experts at the Dutch embassies and the Ministry of Foreign Affairs in the Netherlands.

Given the cross-sectoral nature of urban planning, the results may also be very useful for informing discussions about (1) relation between vernacular community practice in relation to technological innovations (2) changing food systems in the context of urban-rural links, (3) the challenges of halting deforestation and the disappearance of agricultural areas due to the encroaching city and (4) understanding of appropriate support in dealing with the challenges of climate change in such context.

The research design of this study has a qualitative approach, and uses exploratory research through case study analysis to identify the types of NBS, capital and cooperation appropriate in the specific context. The case study analysis allows for a 'mixed methods' approach including literature review, spatial analysis (systemic approach with qualitative and quantitative aspects), governance analysis (institutions, stakeholders, finance) and SDG evaluation. The first step was the literature review to create an identification framework to be able to place the NBS in the specific context. Second step was the literature review on the state-of-the-art of NBS in vulnerable geographies and the identification of a long list of case studies. The third step was a selection and projective (design oriented) analysis of a short list of exemplary case studies that have been subjected to spatial and institutional reading.

As main outcomes, this research delivers a *theoretical and conceptual framing* of the qualitative approach by means of the *identification framework*, an inventory of 40 cases of vulnerable geographies in extreme landscapes, the *long list*, and the projective analysis of six selected cases, the *short list*. The short list analysis puts the design, planning and governance into context, pointing out trade-offs and synergies between effects (inclusive – green) of the studied NBS, locating them in specific geographical and institutional contexts.

The scale of the project limited the extension of analysis but as an approach, the research has opened the perspective on niches in the field. In this sense, it has delivered some preliminary findings on the feasibility, the capital, the dependencies, and co-benefits-presented in the preliminary discussion and conclusion, and a rich list of recommendations for further research.

2. Research methodology

2.1 Research aim & questions

Building on the work *the geography of future challenges* (PBL, 2018), the aim was to explore the outreach of examples of NBS (already implemented or under study) applied in 'vulnerable geographies', contexts that are underdeveloped, have a weak institutional context, a high inequality and are in extreme landscape. The specific water challenges that these vulnerable geographies are dealing with are: too much, too little, too polluted water. The investigation is aimed at learning from the type of solutions selected in each case; where they are applied (within the urban area, peri-urban area, upstream); and how (policy, community practice, physical intervention).

The objective of the research is to identify the typology of water related NBS solutions in vulnerable geographies, their implementation approach and long term impact in geographical and institutional contexts where urban growth, informality and illegality but also climatic extremes are highest and access to economic resources are lowest.

To this aim, the two guiding research questions are:

(RQ1)Which types of NBS are appropriate in socio-economic unequal urban and peri-urban contexts with extreme water-related challenges?

(RQ2) Which types of capital and cooperation are appropriate in these contexts?

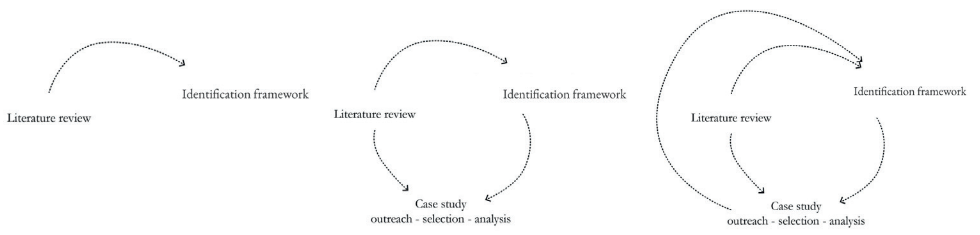
2.2 Research methodology &methods

The research methodology is based on the systems approach (see section 3.1). By means of literature review and case study analysis, the system overview delivers a qualitative understanding of vulnerable geographies.

The literature review had a double purpose, on the one hand it is used to construct and inform an *identification framework* to read the cases, allowing us to recognise the environmental, socio-spatial and institutional parameters shaping the water-related challenges. On the other hand, it worked to gather case studies for too much, too little and too polluted water-related challenges (PBL, 2018).

With this approach, the study of cases is guided by the identification framework providing a structure the way of reading the information, while the case study informs, complets and adjusts the framework itself (see figure 2).

Figure 2
Research Approach
Source: TU Delft



3. Theoretical & Conceptual exploration: Identification Framework

3.1 Systemic approach

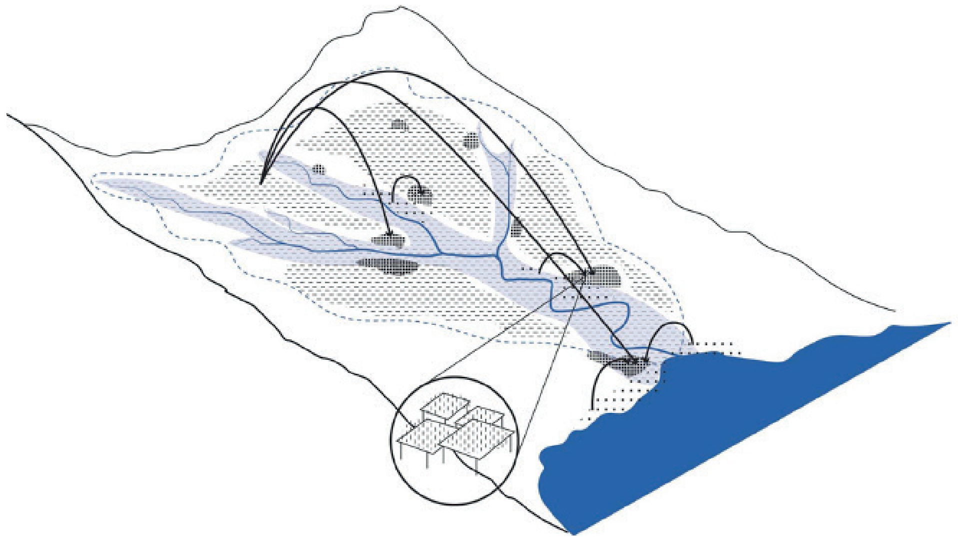
The systemic approach is a common methodology in the discourse of Delta Urbanism in reading, projecting and evaluating spatial conditions and interventions. Delta Urbanism is a discourse that explores and exploits an integrative and interdisciplinary approach in the planning, designing and engineering of urbanised deltas – fragile and highly dynamic landscapes at sea, in deltas, and in estuaries – facing extreme challenges from competing claims and interests (Bacchin, Hooimeijer, Kothuis, 2020).
From a systemic perspective, the exploration of "NBS in urban and peri-urban settings" is not constrained to actions within the urban and peri-urban context necessarily. Meaning that actions taken at the scale of the city have consequences downstream, but also actions taken in rural or productive areas upstream and outside the city have an impact at the city level, improving or worsening urban water-related challenges. In this sense, since the city cannot be considered an isolated island, but takes part in a larger regional system, the watershed, the research will broaden the search for NBS throughout the watershed.

As portrayed in figure 3, the rural, peri-urban, urban areas, but also the block is interrelated within the same basin, affecting and retrofitting each other in different ways.

Figure 3
System of NBS
Source: TU Delft

Legend

- Urban areas
- Peri-urban areas
- Rural areas
- Urban block
- Watershed
- River
- Floodplain
- Coast



Actions taken at the urban scale have consequences in rural and urban areas downstream, but also actions taken in rural or productive areas upstream have an impact at the city level, improving or worsening urban water-related challenges. In this sense, since the city cannot be considered an isolated island, but takes part in a larger regional system, the research will broaden the search for NBS throughout the watershed. The position of a project in the watershed is defined with the Topographical Position Index (TPI) the composition of information related with the position in the watershed (upstream, middlestream, downstream) and the slope (flat or vertical).

This systematic way of reading NBS is transcalar in a spatio-temporal sense, where administrative scales are put in relation with hydrological and biotic scales (Bacchin T.K, 2015). It categorizes different types of NBS from local to systemic and from planning to governance.

With this modus operandi, the investigation is into how NBS perform in urban living environments, impact environmental, socio- economic aspects, institutions and governance (see figure 4 and 5) at a:

- macro-catchment level, NBS perform as connecting patches and corridors enhancing the performance of regional ecological matrixes;
- meso-scale level, NBS articulate urban living and form but also address hydrological and ecological connectivity, restoring the water cycle performance from a city-scale perspective;
- micro-scale level, NBS are designed urban spaces composing different types of areas -ponding areas, permeable pavements, green spaces- that dialogue with the urban programming and landscaping of the block.
- nano-scale level, NBS are material artifacts responsive to different rainfall events shaping different spatial experiences and seasonal change – specific choice of technologies at the plot (land unit) level.
- process scale, NBS correspond to the abiotic, biotic and cultural benefits of the designed solutions.

Figure 4
Performance relations
Source: Bacchin, 2015

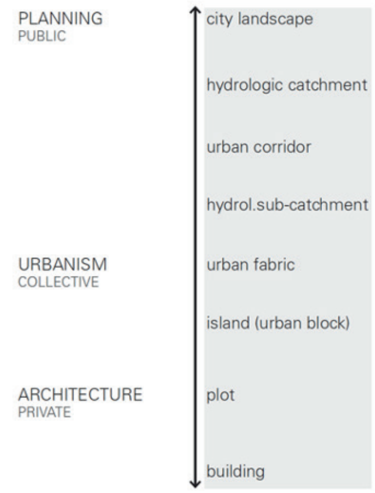


Figure 5
Performative scales
Source: Bacchin, 2015

3.2 Identification framework

The identification framework was developed to support systemic understanding of contextual conditions (environmental, socio-spatial-institutional context) that identify the type of NBS and its implementation, or the applicability and appropriateness of solutions in vulnerable geographies. Figura 6 is the summary of the framework that is presented more in detail in figure 7. The figures 8, 9, 10 and 11 are detailled elaborations of the Identification Framework.

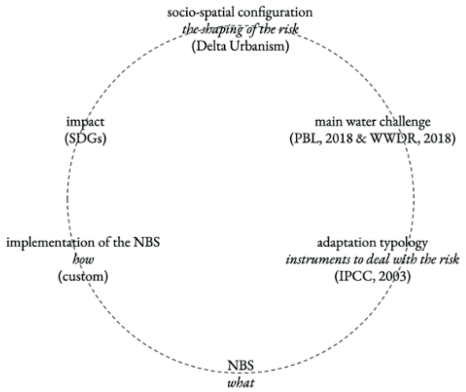


Figure 6
Summary Identification Framework
Source: TU Delft

Figure 7
Full Identification Framework that is fundamental to this research
Source: TU Delft

The line of reasoning to get to this understanding has four main components:

context reading	*NBS*	*implementation*	*impact*

The case study design follows this way of reading through the framework, and is structured accordingly:

Context reading
a. Context to water stress
Reflecting on how the geographical positioning, socio-spatial and institutional context shape the water-related challenge.

NBS
b. Water stress to NBS
Including the entire NBS taxonomy, from water stress, main aim of the NBS, sphere of implementation, addressed ecosystem, type of cooperation and type of capital.

Implementation
c. NBS implementation
Developing in more detail the sphere of implementation, addressed ecosystem, type of cooperation and type of capital.

Impact
d. NBS impact
Reflecting on how the adopted strategy falls into the NBS principles defined by Cohen-Shacham et al., (2019); the social, ecological and economic synergies and tradeoffs coming from the implementation of the NBS; and the impact into the achievement of SDGs.

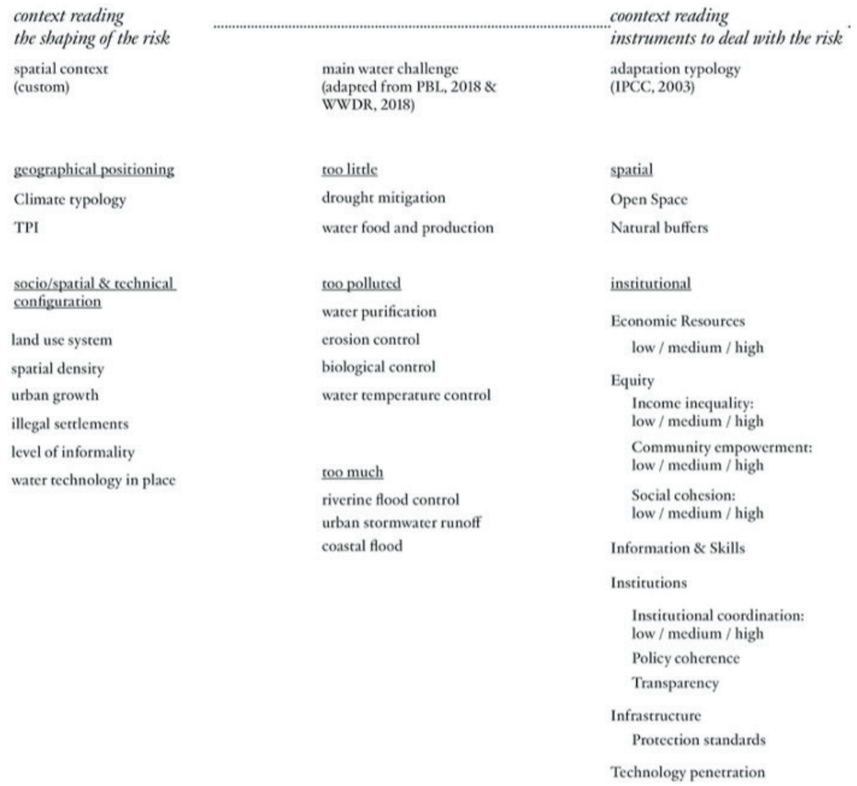
e. Scalability and lessons learned

3.2.1 Context reading

The context reading provides key insights in the shaping of the water-related risk. In order to do so, a first analysis of the geographical positioning takes place, identifying the climate typology as tropical, subtropical or desert and TPI, Topographical Position Index defined by Delta Urbanism research group as the composition of information related with the position in the watershed (upstream, middlestream, downstream) and the slope (flat or vertical). Next, the analysis of the socia/spatial & technical configuration takes place. This is defined by the land use system, population growth rate, urban growth, illegal settlements, level of informality and water technology in place.

With the above elements, the main challenge is framed and the nature of the water-related problem is understood. This is followed by the understanding of the instruments to deal with the risk, or the adaptation typology (IPCC, 2003). These instruments can be spatial, like open space and natural buffers; institutional, like economic resources, equity, information & skills, institutions and infrastructure.

Figure 8
Context reading in Identification Framework
Source: TU Delft



This research takes the parameters and categories used in the "framework for estimating adaptive capacity of urban settlements" developed by Sušnik & Veerbeek (2020) as a starting point (see figure 9).

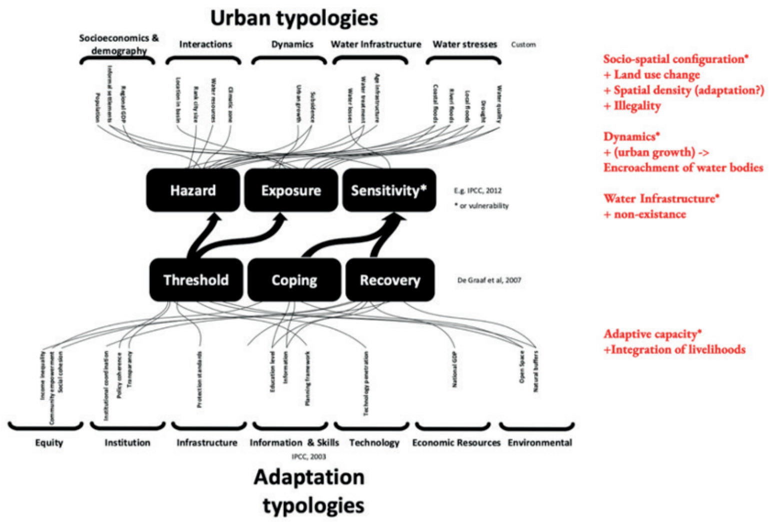


Figure 9
Framework for estimating adaptive capacity of urban settlements.
In red , the main points that are added through context reading
Source: Sušnik & Veerbeek, 2020

According to this quantitative framework of IHE, the assessment of a city's capacity to deal with a water-related challenge is assimilated with the function of risk as a function of hazard, exposure and sensitivity (IPCC, 2012) and adaptive capacity as long term adjustment of threshold, coping and recovery capacity (De Graaf et al., 2007).

In this sense, urban typology (Sušnik & Veerbeek, 2020) corresponds to the assessment of the performance of a city towards a risk; and adaptation typology (Sušnik & Veerbeek, 2020) defines its capacity for future adaptation. In other words, urban typology is a notion that shapes the understanding and nature of the risk, and the adaptation typology collects the instruments to deal with the risk.

In order to include a qualitative side of these urban typologies, supportive of a spatial and design perspective, this research spots two key insights:

1. *The acknowledgement of the adaptive capacity within the adaptation typology*

The objective of adaptive capacity is building an understanding and an ability to foresee developments for the future in which the main goal is to establish a robust and healthy living environment, making use of all three other capacities, threshold, coping and recovery, as an ensemble (De Graaf, 2009). In his publication, The Nature of Urban Design: a New York Perspective on Resilience, Washburn (2013) proposed the risk formulae as Risk = (probability-mitigation) x (consequence-adaptation). In this sense, adaptation is connected to *livelihood*, where the role of space is made clearer.

For example, the design of flood defences has a large impact on the surrounding environment including highly valued natural and cultural landscape features and the lives of people (Van Loon-Steensma & Kok, 2016). Flood defences are not only an infrastructure for safety, but also "the symbol of the relationship between man and nature, an identity of people, landscapes and countries" (Palmboom, 2017).

2. *The inclusion of land use change, spatial density and illegal settlements as new parameters within the urban typology.*

Land-use change is a parameter that signifies if land is performing within the natural system or performing as part of the human system, especially if it includes soil sealing of the land. Water systems are affected by the land use and if the land is covered or not, which affects the permeability and will degrade the riparian ecosystem services (Wagner et al. 2013; Khan et al. 2017). Anthropogenic activities such as agriculture, deforestation and urbanization have been identified as the main drivers of land use and land cover change which affects the quality of water bodies (Khan et al. 2011; Olusola et al. 2018). Land use within a watershed thus has a great impact on the water quality and quantity of rivers (Li et al. 2014).

For the analysis of land-use change, PBL took the settlement layer of GHSL (version 2016) for the years 1990 and 2015 to present the land-use changes. This is done for the urbanized area, the urbanized area plus a buffer of 10 km and a buffer of 25 km. These ratios are also related to the national scale.

Spatial density in a spatial perspective is related to subjects such as sustainability, mobility and transport, local environment and real estate prices. PBL has developed a method for automating the calculation of spatial density, expressed in FSI (Floor Space Index) and GSI (Ground Space Index) and their derivatives L (Layers) and OSR (Open Space Ratio), in order to allow for nationwide, generic calculation. These indices, in accordance with the Dutch NEN9300 standard at city block, neighbourhood, district and municipal scales, are provided in the RUDIFUN data set.[1] These indices not only show spatial density data, but also offer insight into the urban morphology of the local, physical environment (Berghauser Pont and Haupt, 2010).

[1] see for more information ww.pbl.nl/en/publications/spatial-density-and-mix-use-in-the-netherlands-rudifun).

Urban Illegality is often related to the occupation of protected land by environmental laws. The illegal and informal (precarious) occupation of land located in floodplains, coastal zones, or land subject to landslides and erosion is a common phenomenon found in vulnerable geographies where urban property rights and housing are inaccessible to many due to high levels of poverty. According to Fernandes (2001) "it is widely acknowledged that urban illegality has to be understood not only in terms of the dynamics of political systems and land markets, but also the nature of the legal order, particularly the definition of urban real property rights." In this context, the promotion of urban reform for land rights is a prerequisite of human safety, risk management and environmental conservation practices.

context reading	*NBS*	*implementation* *impact*

3.2.2 NBS

Nature Based Solutions is a well-known term, broadly used among researchers and practitioners, not always referring to the same. In this research, the terminology elaborated by the International Union for Conservation of Nature (IUCN) is used, which, in words of Cohen-Shacham et al., (2016) includes:

"actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity."

With this accepted definition, it can be noticed that NBS are not only confined to nature-based technical solutions or physical interventions. They come in the shape of "actions" that, no matter their nature, "protect, sustainably manage, and restore natural or modified ecosystems" while addressing societal challenges that provide "human well-being and biodiversity". This research took the aforementioned principles to reflect on the impact of NBS in the studied locations (see chapter 4.4).

context reading	NBS	implementation	impact

3.2.3 Implementation

The reading of the implementation of NBS is done along the following lines:

- sphere of implementation: physical intervention, community practice or policy guidelines,

- scale of implementation-urban/peri urban scale, basin scale and addressed ecosystem point, corridor, patch, network, matrix,

- type of cooperation: household, community, municipal, intermunicipal, national or international,

- type of capital: social, financial.

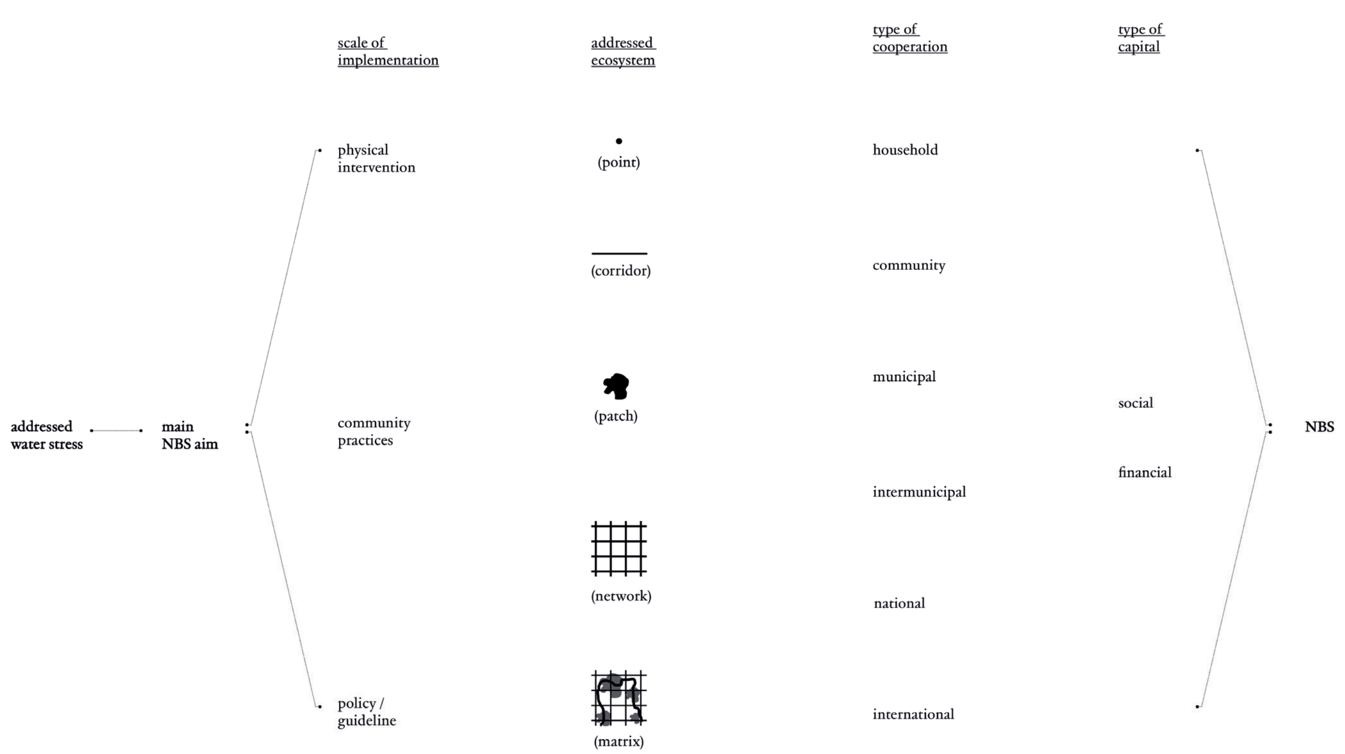


Figure 10
Diagram of implementation aspects
Source: TU Delft

Sphere of implementation

The long list of case studies delivered insight on three spheres of implementation in which NBS can take place: as policy guidelines, spatial interventions and community practices.

Policy guidelines

Policy or planning guidelines are policy instruments that recognise, protect and manage systemic water-soil relations at different scales.

Examples of this are:
-Catchment protection policies
-Sponge City Concept
-Regulation/Recognition of Peri-Urban Agricultures in planning
-Coastal zone development regulations
-Mangrove zone protection regulations
-Groundwater regulations
-Support of traditional land management practices and ITEK

Source:
1. Gorakhpur project map area; GEAG, 2016
2. Chennai floods (n.d).
3. Mangrove recovery behind permeable dams by PT. Prospek Empat Dimensi (n.d).

Spatial interventions

Such as structures, aggregates or surfaces that physically transform the current status and create the conditions for dealing with the water-related challenges, either for flood protection/buffering, for water de-pollution or for ensuring water availability.

Examples of this are:
-Sand-dams that retain and store groundwater for irrigation
-Re-vegetation of buffer areas (river banks and floodplains)
-Constructed wetlands
-Restoration of water ponds
-Permeable, low-cost structures that fixate sediment and reclaim new land
-Low-cost green roofs

Source:
1. Communities along the Kok Noi riverbank are involved in the river restoration to improve water circulation and water quality; Photo: TEI.
2. Permeable structures by Nanang Sujana (n.d).
3. After restoration a floating island in the middle of Indore Lake used for water purification by Tejas Patel (n.d).

Community practices

Mostly in the form of land management practices, which either enabled by planning guidelines, and sometimes by means of physical interventions, include the livelihoods of inhabitants most affected by the water-related challenge. These are key for strengthening the adaptive capacity of the inhabitants, where risk and livelihood come closest, delivering long-term social/behavioural change.

Examples of this are:
-Sustainable agricultures ensuring livelihoods under flood conditions
-Collection of waste
-Cultivation of new land reclaimed to protect the coast

Scale of implementation and Addressed ecosystem

The scale of implementation of NBS refers to the urban/peri-urban scale in relation with the basin scale (see figure 3). Spatially, the NBS is represented in the aspects point, corridor, patch, network, and matrix (Dramstad, Olson, & Forman, 1996).

Type of cooperation

The type of cooperation is related to the sphere of communication and connected to the type of capital invested. The case study analysis led to identification of the household, community, municipal, intermunicipal, national or international types that describe the impact level and relation to SDG's.

Type of capital

The type of capital invested goes beyond a monetary meaning, expanding to the central notion of the 'sustainable livelihoods perspective' (Odei Erdiaw-kwasie & Basson, 2017). According to Odei Erdiaw-kwasie & Basson (2017), there are five livelihood assets, which the poor must often make trade-offs and choices about:

Human capital health, nutrition, education, knowledge and skills, capacity to work, capacity to adapt;
Social capital networks and connections (patronage, neighbourhoods, kinship), relations of trust and mutual understanding and support, formal and informal groups, shared values and behaviours, common rules and sanctions, collective representation, mechanisms for participation in decision-making, leadership;
Natural capital land and produce, water and aquatic resources, trees and forest products, wildlife, wild foods and fibres, biodiversity, environmental services;
Physical capital infrastructure (transport, roads, vehicles, secure shelter and buildings, water supply and sanitation, energy, communications), tools and technology (tools and equipment for production, seed, fertilizer, pesticides, traditional technology);
Financial capital savings, credit and debt (formal, informal), remittances, pensions, wages;

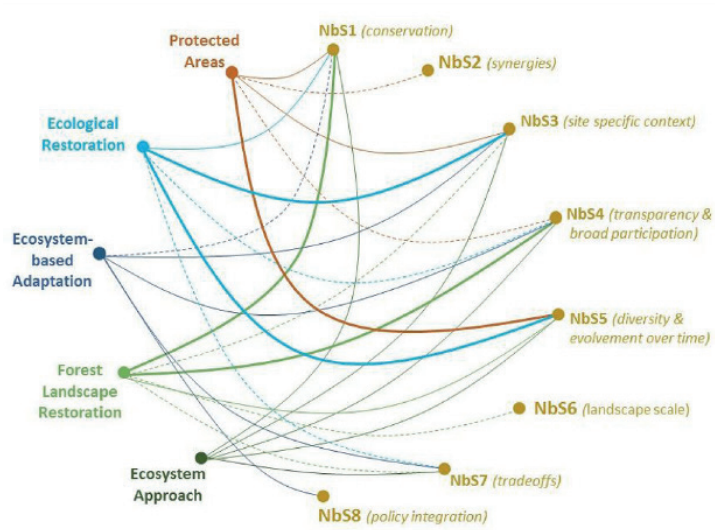
For the assessment of cases (chapter 4.4), only the social capital and the financial capital (public/private investments) were mapped due to the scale of the project.

3.2.4 Impact

The assessment of the impact of NBS in the case study analysis follows, on the one hand, the IUCN & CEM (2016) principles, and on the other hand, a reflection on the SDGs.

Principles for sustainable implementation of NBS
According to Cohen-Shacham et al., (2016), eight principles can be identified for the successful implementation of NBS: embracement of nature conservation, triggering of a myriad of social, economic and environmental synergies, site-specific, enabling of transparency and broad participation, involvement over time, embedded within a landscape scale, considerate to short-term tradeoffs, and involving policy integration.

Figure 11
Principles for successful implementation of NBS.
Source: Cohen-Shacham et al., 2016



SDGs

In 2015 the United Nations (UN) established the 2030 Agenda for sustainable development with the aim of eradicating extreme poverty, reducing inequality and protecting the planet. The Agenda 2030 highlights the importance of biodiversity and the functioning of ecosystems to maintain economic activities and the well-being of local communities. NBS are increasingly seen as innovative solutions that support the achievement of several Sustainable Development Goals (SDGs) in a broader sense, transforming natural capital into a source of green growth and sustainable development. NBS promote the delivery of bundles of ecosystem services together generating various social, economic and environmental co-benefits. However, to achieve the full potential of NBS, it is necessary to recognize the trade-offs and synergies of the co-benefits associated with their implementation. To this aim Gómez Martín et al. (2020) have adopted a system perspective and a multi-sectoral approach to analyse the potential of NBS to deliver co-benefits while at the same time reducing the negative effects of water-related hazards, in European context. They conclude that assessing the dynamic behaviour of trade-offs and synergies among co-benefits could help to anticipate, identify and solve resistance to adopt policies and suitable strategies to implement NBS. Their method of analysing the water system in its multifunctionality, and its capability to produce benefits over time supported 1) the integration of quantitative and qualitative variables, knowledge and issues that are not well-defined or uncertain, and 2) show the complex interconnections and feedback processes within the system helping to infer intended and unintended consequences of NBS implementations and 3) the analysis promoted awareness and motivation of those taking part in decision- or policy-making processes, thus providing a platform for the joint-ownership of results (Gómez Martín et al., 2020).

4. Case study review

4.1 Search strategy

The search for case studies starts by exploring the initiatives and projects being developed by key water platforms. It should be noted that when compared to the Western world, there are not many cases. Due to this limited pool the cases have foremost an exemplary value. Each of initiatives and/or platforms provided a different type of information and projects from which the research was expanded:

Cap-Net
Capacity building for Integrated Water Resources Management to related professionals in the Southern African regions
link: https://cap-net.org/waternet/

ACCCRN
Platform collecting knowledge and examples building Inclusive Urban Climate Change Resilience on poor and vulnerable communities
link: https://www.acccrn.net/

UN-IHE
Platform collecting and generating knowledge in capacity building
link: https://www.un-ihe.org/

UN-Water
Reports arising from UN-Water show the potential of nature-based solutions (NBS) to address contemporary water management challenges across all sectors, and particularly regarding water for agriculture, sustainable cities, disaster risk reduction and water quality
link: https://www.unwater.org/

IUCN
Platform focused on policies informed by NBS for the Conservation of Nature
link: https://www.iucn.org/nl

FAO
Platform connecting Nature-Based Solutions with agricultural water management and food security
link: http://www.fao.org/

IRC
IRC works around the world promoting sustainable WASH systems (Water Access, Sanitation, and Hygiene) and in six focus countries: Burkina Faso, Ethiopia, Ghana, Honduras, India and Uganda - a network of people and things working together to deliver WASH services in the long term
link: https://www.ircwash.org/

Oppla
The platform is a EU repository of NBS around the globe
link: https://oppla.eu/case-study-finder

4.2 Case study outreach

Coming from the work on the geography of future challenges (PBL, 2018), the exploration started with examples of NBS (already implemented or under study) applied in poor, underdeveloped extreme landscapes challenged by too much, too little, too polluted water (see figure 12).

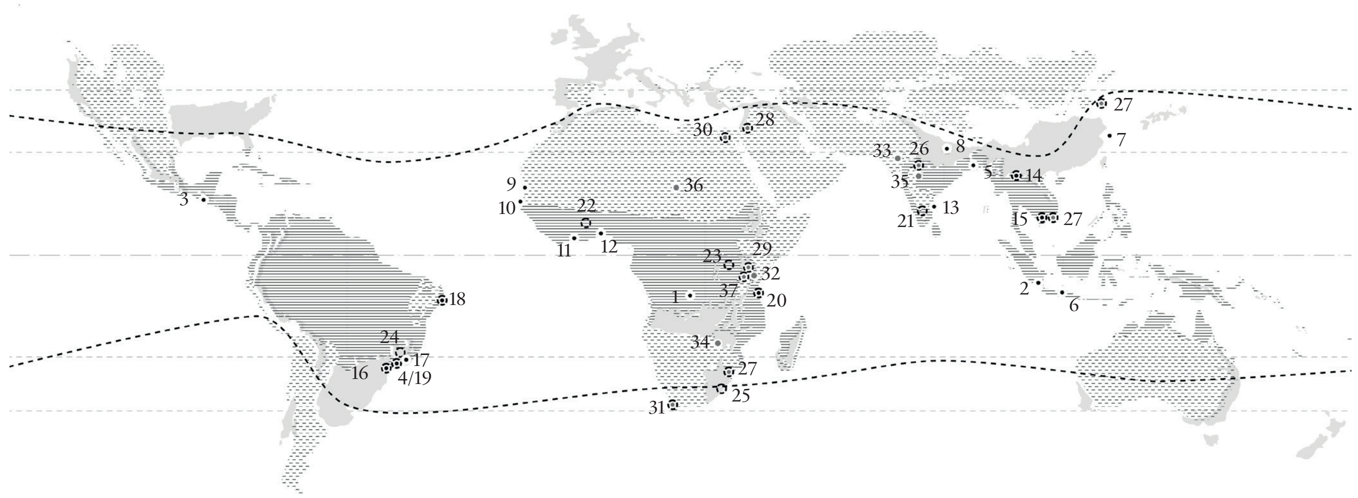


Figure 12
Case Study Outreach, longlist
Source: TU Delft

1. Kasangulu, Republic of Congo
2. Bandar Lampung, Indonesia
3. San Marcos, Guatemala
4. Arara slum, Brazil
5. Khulna, Bangladesh
6. Semarang, Indonesia
7. Ningbo, China
8. Gorakhpur, India
9. Nouakchott, Mauritania
10. Dakar, Senegal
11. Grand Lahou area, Cote d'Ivoire
12. Ouidah, Benin
13. Chennai, India
14. Chiang Rai, Thailand
15. Can Tho, Vietnam
16. Sao Paulo, Brazil
17. Niteroi, Brazil
18. Recife, Brazil
19. Rio de Janeiro, Brazil
20. Dar-es-Salaam, Tanzania
21. Ganjam, India
22. Asufi ti North District, Ghana
23. Kampala, Uganda
24. Petropolis, Brazil
25. Durban-Pietermaritzburg, South Africa
26. Indore, India
27. Peri-urban Great Maputo, Mozambique
Tra Vinh Province, Vietnam
Laizhou Bay, China
28. Zarqa River Basin, Jordan
29. Lake Naivasha, Kenya
30. Bilbeis, Egypt
31. Cape Town, South Africa
32. Tana-Nairobi, Kenya
33. Rajastan, India
34. Shashe, Tuli and Sashne Rivers, Zimbabwe
35. Burhanpur, India
36. Great Green Wall, Sahel
37. Mau Forest Complex, Kenya

The distribution over climate zones and the typical water-related challenge the cases were dealing with were the main boundary conditions for the case study outreach.. The long list can be found in the appendix and shows a wide overview of approaches in a very diverse context. From this pool six cases were chosen to study more in depth.

4.3 Case study selection

4.3.1 Selection criteria

The criteria to select six cases from the long list were:

a. Diversity of cases across the globe
b. Diversity of climate typology and water-related challenges (too much, too little, too polluted)
c. Extensive and available information on the case.

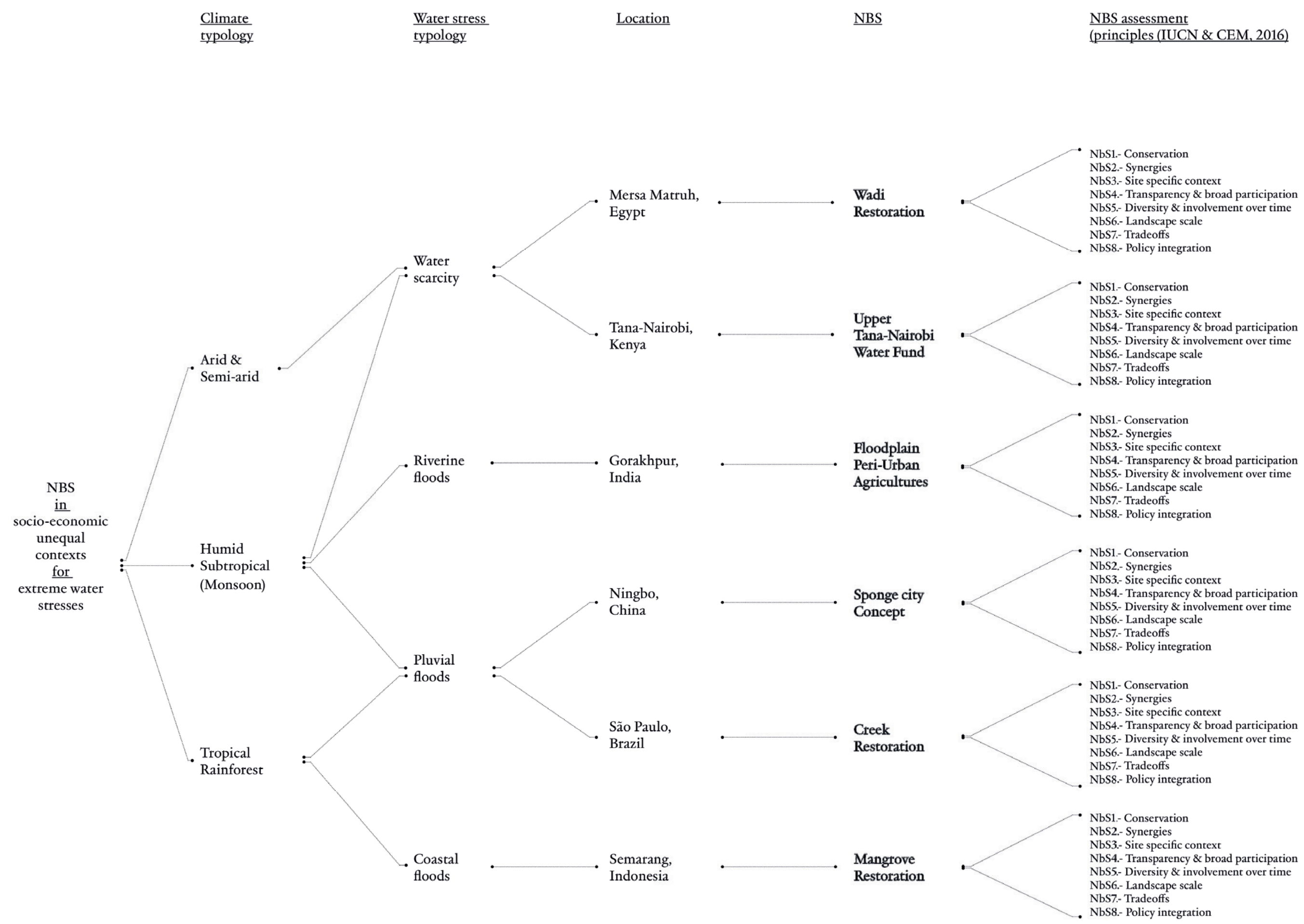


Figure 13
Case Study Taxonomy
Source: TU Delft

4.3.2 Selected cases

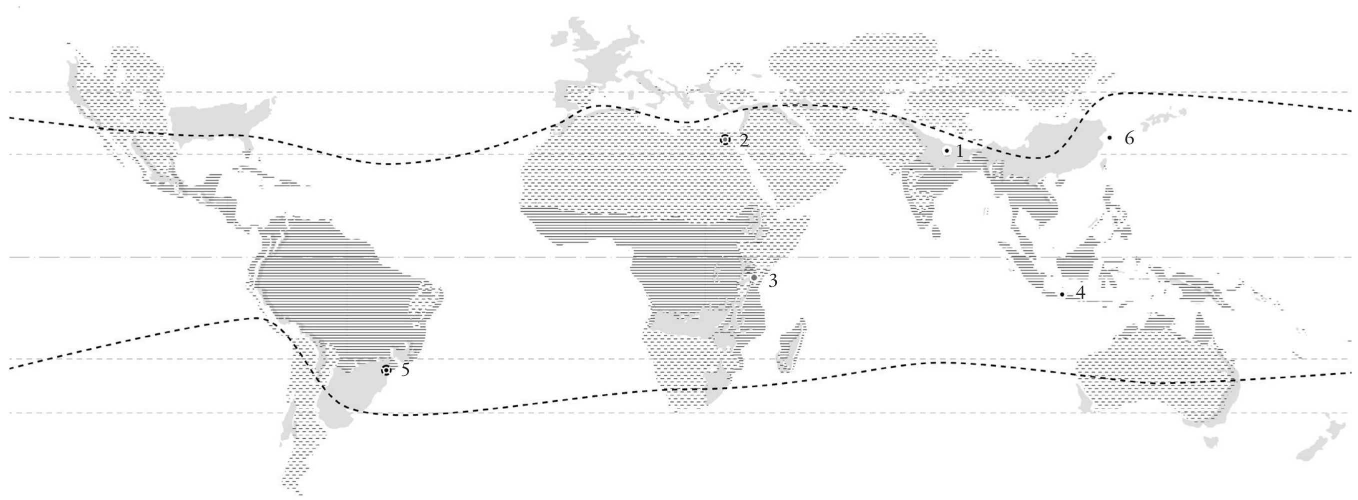


Figure 14
Case Study Selection
Source: TU Delft

1. Gorakhpur, India
2. Mersa Matruh, Egypt
3. Tana-Nairobi, Kenya
4. Semarang, Indonesia
5. Sao Paulo, Brazil
6. Ningbo, China

4.4
Case Study Analysis

4.4.1
Urban riverine flooding
Peri-Urban Agricultures
Gorakhpur, India

Waterlogged housing in Gorakhpur, India
Source: Du, J. (2019); photo by Anna Brown

context reading
the shaping of the risk

spatial context
(custom)

geographical positioning

Subtropical monsoon climate

TPI= U ↘

socio/spatial & technical configuration

land use system:
Peri-urban agricultures

population growth rate:
high

urban growth:
unplanned

illegal settlements:
low - medium - high

level of informality:
high

water technology in place
non-existent waste system

main water challenge
(adapted from PBL, 2018 & WWDR, 2018)

too little

drought mitigation

water food and production

too polluted

water purification

erosion control

biological control

water temperature control

too much

riverine flood control

urban stormwater runoff

coastal flood

context reading
instruments to deal with the risk

adaptation typology
(IPCC, 2003)

spatial

Open Space

Natural buffers:
Peri-Urban Agricultural Floodplain

institutional

National Economic Resources
- low

Equity
- Income inequality: medium
- Community empowerment: high
- Social cohesion: high

Information & Skills

Institutions
- Institutional coordination: high
- Policy coherence
- Transparency

Infrastructure
- Protection standards

Technology penetration

NBS
main aim

Promotion of peri-urban agricultures as the strategy to maintain the availability of open spaces to cope with floods as buffering zones

implementation
of the NBS

(custom)

sphere of implementation
- physical intervention
- community practices
- policy guidelines

scale of implementation
- urban / peri-urban scale
- basin scale

addressed ecosystem
- point
- corridor
- patch
- network
- matrix

type of cooperation
- household
- community
- municipal
- intermunicipal
- national
- international

type of capital
- social capital
- international funding

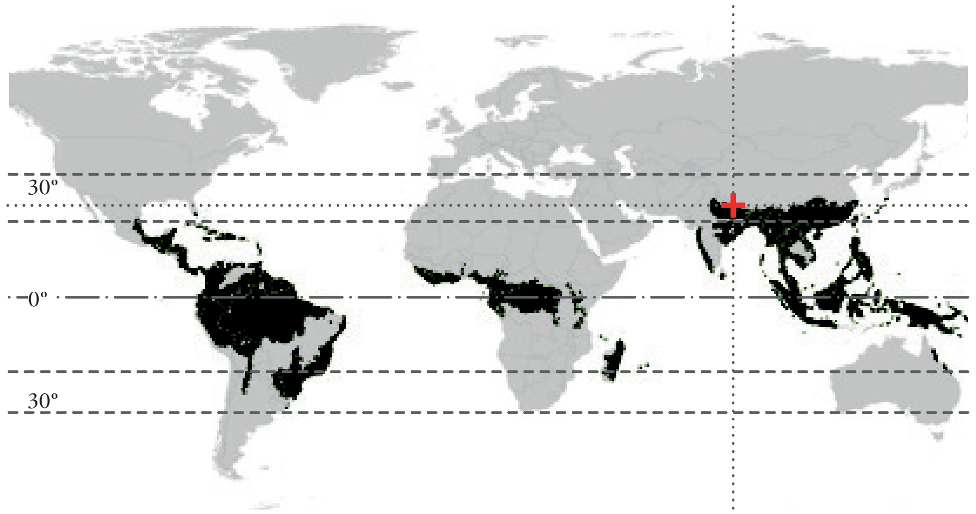
impact
principles & co-benefits

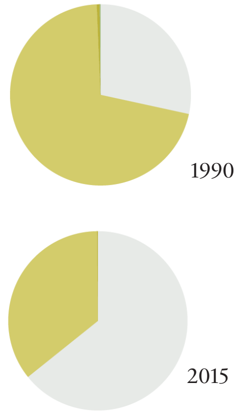
(SDGs)

1. No poverty
2. Zero hunger
3. Good health and well-being
4. Quality education
5. Gender equality
6. Clean water and sanitation
7. Affordable and clean energy
8. Decent work and economic growth
9. Industry, innovation and infrastructure
10. Reduced inequalities
11. Sustainable cities and communities
12. Responsible consumption and production
13. Climate action
14. Life below water
15. Life on land
16. Peace, justice and strong institutions
17. Partnerships for the goals

geographical positioning

■ Subtropical climate
P.D = monsoon
A.P = 1169 mm
T.P.I = U →





socio/spatial & technical configuration

land use system:
Peri-urban agriculture

population growth rate:

type of urban growth:
unplanned

level of informality:

water technology in place:
non-existent sewer system in peri-urban areas

adaptation typology

Natural buffers
Peri-Urban Agricultural Floodplain

National economic resources

income inequality

community empowerment

social cohesion

information & skills

institutional coordination

keywords

subtropical monsoon climate
riverine floods
unplanned urban growth
encroachment of green areas, farms and lakes
degradation of water bodies

The shaping of the water-related challenge

Gorakhpur, a secondary city, located in eastern Uttar Pradesh at the confluence of rivers Rapti and Rohin, has grown rapidly into an economic and institutional hub in the region. Its proximity to Himalayas has made the city susceptible to floods and water logging during monsoon season due to its bowl-shaped topography in relation with the river Rohi and the extreme discharges (Bhatt, Singh & Mani, 2016).

Even though monsoon season has always brought torrential downpours to Gorakhpur, the last few years have seen a record-breaking rainfall that the city is unable to take. As a result waterlogged houses and stagnant floodwaters have made Gorakhpur a hub for diseases such as dengue fever, malaria and Japanese encephalitis (Du, 2019).

However, the city's vulnerability is not only related to its geographical location and climate typology, but it has a strong socio/spatial and institutional component that has dramatically worsen the city's ability to cope with these extremes. The unplanned and rapid urban growth of the city has resulted in the enchroachment of buffer areas such as green spaces, farms and lakes, significantly reducing the city's capacity to deal with floods. Ocurring in the most vulnerable areas, this large scale conversion of agricultural land is happening in the peri-urban areas of Gorakhpur, in their vast majority not legally recognised. This leads to additional vulnerabilities for the poor farmer families living here, where on top of being severily affected by the floods, they do not have access to agricultural services and sewage systems, putting a huge pressure to sell their lands to land developers.

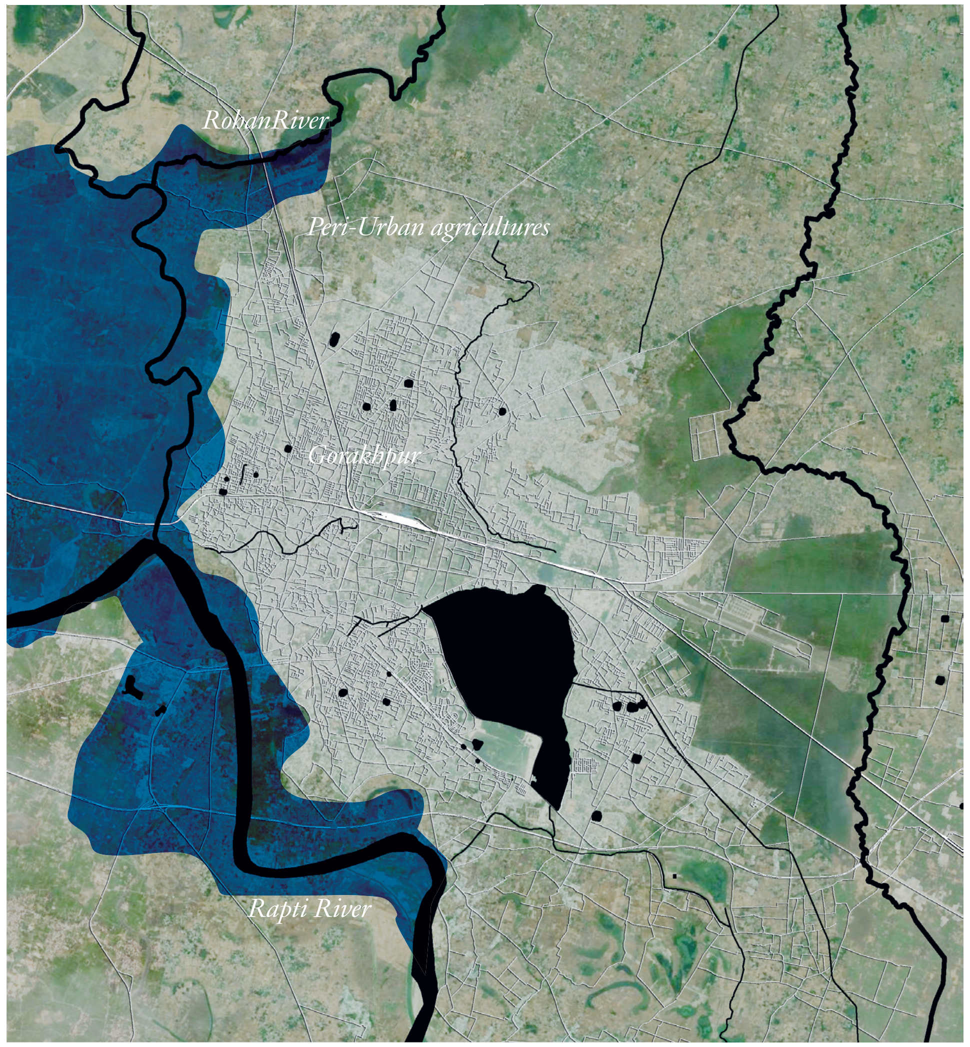
legend

land use (above)
- urban
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

spatial parameters:
- urban grid
- water streams
- water bodies
- peri-urban agricultures

processes:
-unplanned urban growth
-encroachment of water bodies

water stress:
- riverine floods



addressed water stress

main: riverine floods
cascading: water pollution, groundwater replenishment

main aim NBS

preserve and enhance agricultural peri-urban areas to act as flood buffers

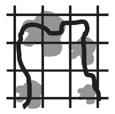
scale of implementation

policy guidelines
- development of climate resilience strategy
- regulations and incentives to manage Gorakhpur's expansion: non-development zones
- improvement of transparency and data collection on land ownership

community practices
- promotion of climate-resilient farming tactics,
- adoption of flood warning system,
- protection of water bodies and drainage channels
- organization of household waste and recycling collection

addressed ecosystem

agricultural patches (acre of land)



system of peri-urban open spaces of agricultural land and low density built up areas

type of cooperation

farmer & farmer

Gorakhpur Environmental Action Group (GEAG) & farmers

Gorakhpur Environmental Action Group (GEAG) & municipality

Asian Cities Climate Change Resilience Network (ACCCRN) & municipality

Asian Cities Climate Change Resilience Network (ACCCRN) & Rockefeller Foundation

type of capital

social
- individual practices and experiences shared as collective knowledge incentivising other farmers to join
- knowledge & tools provided by different platforms so new practices can be incorporated

financial
- private funding to trigger negotiations and research (Rockefeller Foundation)

sphere of implementation

The implementation of the studied strategy is first of all a policy guideline development of climate resilience strategy, regulations and incentives to manage Gorakhpur's expansion through the establishment of non-development zones and the improvement of transparency and data collection on land ownership.

However, it is through a change in community practices that spurs the real change in the sustained protection of open spaces for buffering areas. Among these are: the promotion of climate-resilient farming tactics, the adoption of flood warning system, the protection of water bodies and drainage channels and the organization of household waste and recycling collection.

Interestingly, the sense of confidence provided by successful individual and community new practices instigates innovation and adoption of new technologies around. Such is the case of the Village of Panchayat that constructs a decentralized sewage system with the support of DEWAT's Dissemination Society.

scale of the implementation & addressed ecosystem

Starting by a few acres of agricultural land being managed differently, the addressed ecosystem upscales as a system of peri-urban open spaces and low density built up areas within the larger floodplains of the river.

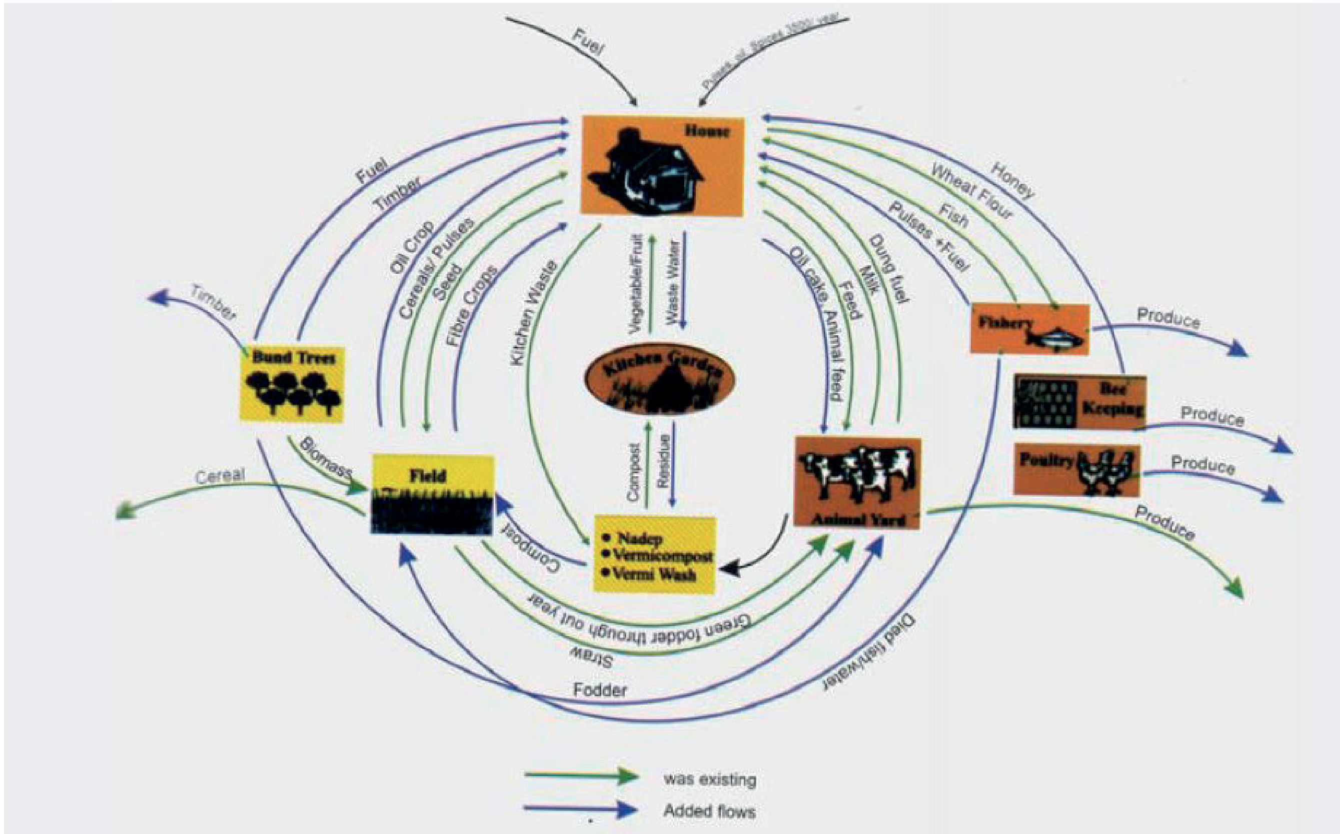
type of cooperation

Rockefeller Foundation - ACCCRN - municipality:
About a decade ago, city officials began developing a climate resilience strategy by means of the Asian Cities Climate Change Resilience Network (ACCCRN) initiative with the support of the Rockefeller Foundation.
ACCCRN - municipality - GEAG:
The support coming from the ACCCRN scheme and municipality spurred wider community efforts led by local non-profit organizations such as Gorakhpur Environmental Action Group (GEAG), to leverage nature-based adaptation for vulnerable and low-income communities at the greatest risk.
GEAG - municipality:
GEAG worked with city officials and regional agencies to put in place regulations and incentives to manage Gorakhpur's expansion. This has helped improve the city transparency in data collection on land ownership and to effectively enforce "no development" zones in open spaces crucial for flood control.
GEAG - farmers:
GEAG partnered with farmers at the city's periphery to implement climate-resilient farming tactics teaching them innovative techniques to secure their livelihoods while improving the quality of their soils and field production.
farmer - farmer:
The learned practices have been spread and shared among other farmers, strengthening the social tissue and community empowerment (see successful stories in page 40).

type of capital

The type of capital that makes this project possible comes first and foremost as a social capital, where individual practices and experiences inspire the upscaling of the strategy by an increasing number of private-farmer initiatives.

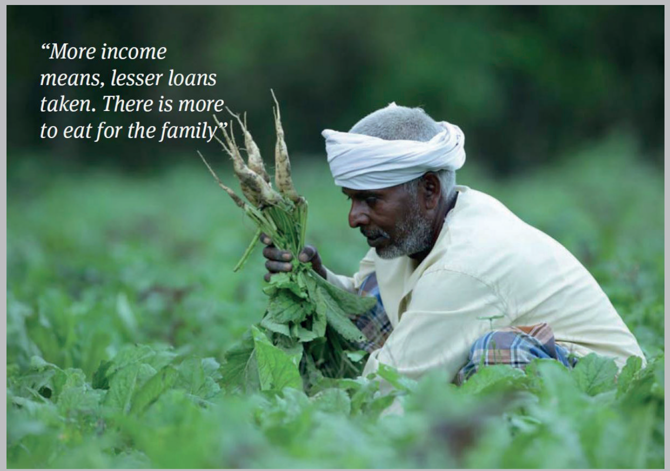
This is not possible without the training, knowledge and tools provided by Agro Service Centers, the Farmers Field School and Gorakhpur Environmental Action Group (GAEAG). But also, the platforms receive financial support by larger Funds and initiatives, as in this case the Rockefeller Foundation.



Integration of farm systems. Retrieved from Bhatt et.al., 2016

NBS impact
Resilient stories

The following page summarizes successful and inspiring stories by peri-urban farmers compiled by (Bhatt, Singh, & Mani, 2016). The portrayed innovations are an effective synergy of science and indigenous traditional knowledge showing how the PUA strategy has provided farmers with a profitable and resilient livelihood, but specially how this has empowered them to protect their land as buffers against floods.



Mahajan Yadav. Retrieved from Bhatt et.al., 2016

Mahajan Yadav,
farmer from Semra Devi Prasad

42% Reduction of market costs due to minimal external inputs
From INR 8-10.000/- to 70,000/- of Net Annual Profit

By attending a training programme on multi-cropping, Mahajan today practices an integrated system of farming with horticulture and animal husbandry producing his own chemical free pesticide and using a self-developed system for irrigation, all of which makes him self-sufficient. This has increased his revenue in a sustained and steady way making him unwilling to sell off his lands to land developers and making him confident that he can hold on to his ancestral land that will pass on to his children. His experience has enabled 25% of his neighbouring farmers to embrace these techniques, helping protect a larger system of agricultural patches. Ultimately is ensuring the protection of the valuable open space as flood buffer to the city.

Asha, "the agriculture lady". Retrieved from Bhatt et.al., 2016

Asha, the "agriculture lady"
Master Trainer from Semra Devi Prasad

conducted 15 training sessions and trained 126 farmers
From INR 14,325/acre to 26,342/acre of Net Annual Profit

Asha joined the Farmers Field School (FFS), an initiative that spurred thanks to the PUA scheme facilitating experimentation, knowledge-sharing, dialogue and shared decision-making. This platform links farmers to agricultural universities and other government departments, giving visibility and training to selected Master Trainers. In this line, additional support comes from Agro Service Centres enabling the availability and quality of inputs. As a Master Trainer, Asha is now a respected woman farmer training fellow farmers to improve the yield production throughout the year, even during monsoon season.

Village of Panchayat Retrieved from Bhatt et.al., 2016

Village of Panchayat,
implementation of DEWATS

150 households involved
3,50 Ha benefiting from direct irrigation from DEWATS

The village of Semra Devi Prasad has no sewerage or drainage system and sewage water was used for irrigation, contaminating the peri-urban land and drinking water resources. A collaboration between farmers providing part of their land and the Consortium for Decentralized Waste Water Treatment (DEWATS) Dissemination Society helping stablish the system, has allowed the village to improve sanitation and reuse sewer water for micro-irrigation.
The successfully implemented system in 2015 now provides "clean water for irrigation, less conflict and healthier people" says Vinod, member of the Panchayati Raj Institution and has set a precedence for other villages led by example.

Kamboj Kumar. Retrieved from Bhatt et.al., 2016

Kamboj Kumar,
Master Trainer in Jharva village

From INR 8,000/- loss of annual income as a result of water logging, to INR 6,000/- annual income after intervention

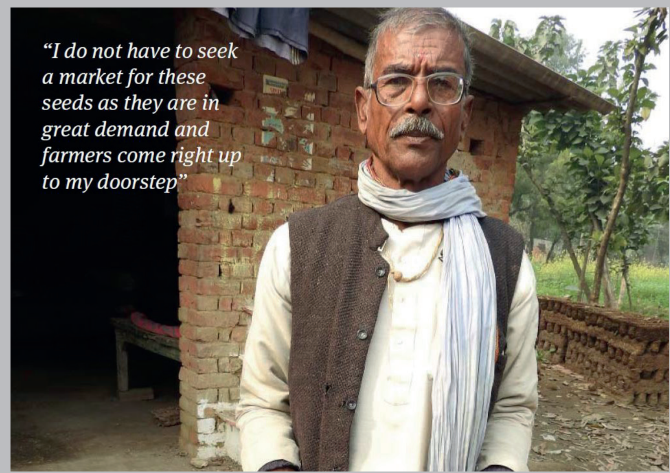
From a very reluctant farmer, Kamboj has now become an active trainer of Low External Input and Sustainable Agriculture (LEISA). Based on ecologically sound principles that are economically feasible, it includes: bio-pesticides, composting, tree plantation, seed treatment and production, helping reduce high costs of external inputs. Trained by the Farmers Field School, he is now a self-sufficient farmer with more profit from vegetable cultivation and better nutrition.

Chanda Devi. Retrieved from Bhatt et.al., 2016

Chanda Devi,
farmer from Sanjhai village

45 crops in a year
INR 28,061/- Net profit per season per acre

By attending the Farmers Field School, Chanda learned from LEISA techniques which helped her family increase their returns significantly. Along with 80 other woman selling their vegetables in the market nearby, they now have a proclaimed place in the market. Chanda has travelled since to many other cities to share her experiences with other farmers and has been interviewed on the local television channel.



Ram Nagina. Retrieved from Bhatt et.al., 2016

Ram Nagina
the seed man

Aware of the importance and scarcity of quality seeds in Gorakhpur, Ram Nagina now cultivates vegetables for seeds which he then sells. The high demand have provided him with an annual income on INR 4,050/-. Ram Nagina has also shared his techniques of seed cultivation with other farmers and has trained 14 people till date.

NBS impact
Principles, synergies & SDGs

NBS principles
(extrapolated from Cohen et.al., 2019)

NbS1.- Conservation
The PUA embraces nature conservation norms and principles as it instigates sustainable management of the soil and vegetation biodiversity through diverse cropping, chemical free pesticides and low energy impact tactics.

NbS2.- Synergies
The PUA groups and spurs a wide range of innovative technologies, inspiring and supporting the experimental side of farmers and helping them tackle other challenges such as the treatment of waste water through DEWATS, or adopting healthier approaches to nutrition but also to pollution.

NbS3.- Site specific context
As described in the successful stories, PUA combines a range of scientifically advanced and low-tec technologies with traditional knowledge on the type of crops (millets) that better withstand monsoon seasons and floods

NbS4.- Transparency & broad participation
The success of the PUA is intrinsically related with the different levels of cooperation and participation, from the international network ACCCRN recognising the space of opportunity, to a municipality opened to the establishment of climate resilient guidelines including the transparency in land ownership and the establishment of non-development areas, to the community platforms supporting individual farmers, ultimately instigating a broader cohesion among marginal and poor families.

NbS5.- Diversity & involvement over time
Thanks to the support of a diversity of learning and tool-provisioning platforms, the ultimate implementation of PUA takes place locally by the farmers themselves. In this sense, a broader a broader network of successful experiences increases the involvement of more farmers and agricultural patches over time, securing and expanding the scope of buffering areas.

NbS6.- Landscape scale
Implemented at a patch level (acre of agricultural land), the expansive character of the initiative looks at the floodplain level.

NbS7.- Trade-offs
The understanding of short term efforts, including a more demanding attention and hard work in the multi-cropping plantation is well interiorised by farmers who are encouraged by sustained incomes throughout the year and future long-term benefits in increasing flooding resilience of the city.

NbS8.- Policy integration
The innitiative involves the development of a municipal climate resilience strategy, regulations to planning and establishment of non-development zones, improvement of transparency and data collection on land ownership. As a stating point, this spurs the development of different platforms locally supporting the farmers making the most of their land and stop them from selling it. However, stronger efforts in policy integration of peri-urban areas into the planning of the city would help upscale the intervention.

synergies / trade-offs
(provided by the study)

environmental synergies / trade-offs
- Reduction of the energy footprint by diversifying the food sources
- Preservation of local biodiversity
- Recycling of urban waste

social synergies / trade-offs
- Enhancement of coping capacity to deal with flood impacts
- Nutritional security
- Social cohesion, collective support for community goals
- Food security
- Livelihoods of small and marginal farmers
- Empowerment of women's knowledge and voices
- Support for social and technological innovation

economic synergies / trade-offs
- Diversification of income sources
- Boosting crop yields and farmer's incomes by one-third
- Long-term savings in flood damages

SDGs
(extrapolated from synergies)

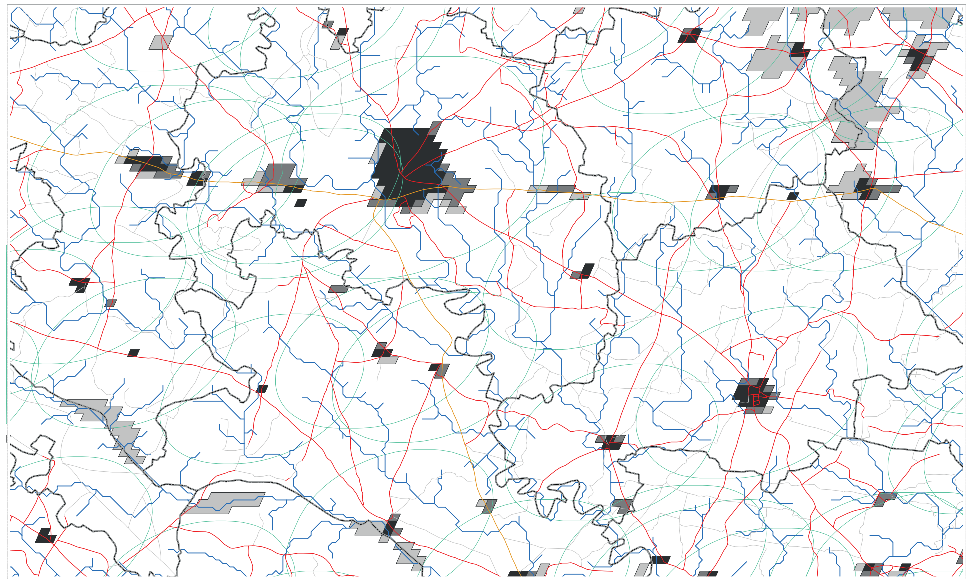
1 No poverty
2 Zero hunger
3 Good health and well-being
4 Quality education
5 Gender equality
6 Clean water and sanitation
7 Affordable and clean energy
8 Decent work and economic growth
9 Industry, innovation and infrastructure
10 Reduced inequalities
11 Sustainable cities and communities
12 Responsible consumption and production
13 Climate action
14 Life below water
15 Life on land
16 Peace, justice and strong institutions
17 Partnerships for the goals

basemap

legend

- administrative boundary
- roads
- highway
- fast transit road
- regional road
- main road
- local road
- water
- water body
- river
- urban area
- urban area in 1990
- urban area in 2000
- urban area in 2015
- 10 km around urban area in 1990

0 25 km N



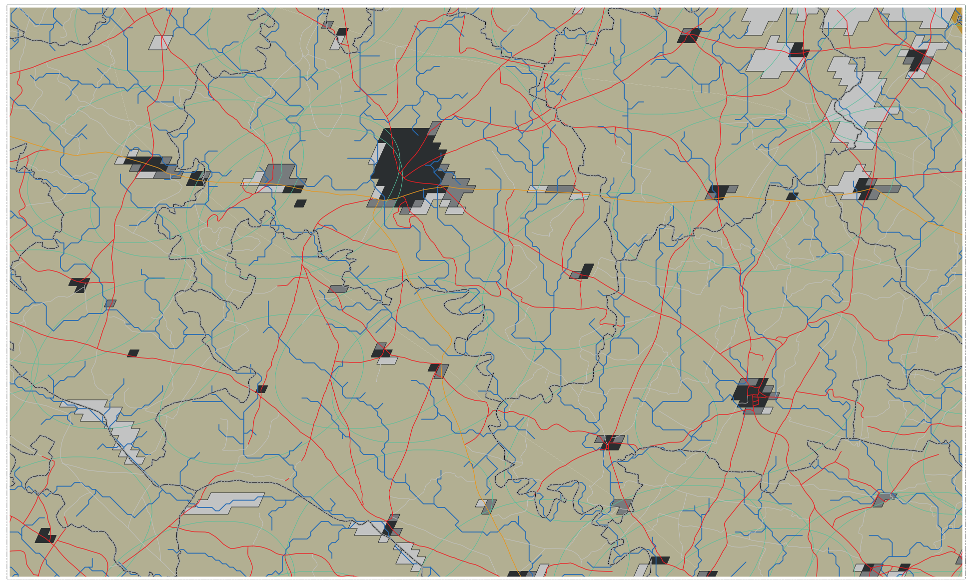
Source: PBL

soil map

legend

- Acrisols
- Cambrisols
- Chernozems
- Podzoluvisols
- Rendzinas
- Ferrasols
- Gleysols
- Phaeozems
- Lithosols
- Fluvisols
- Kastanozems
- Luvisols
- Greyzems
- Nitosols
- Histosols
- Podzols
- Arenosols
- Regosols
- Solonetz
- Andosols
- Rankers
- Vertisols
- Planosols
- Xerosols
- Yermosols
- Solonchaks
- S2-3a
- W2-a

0 25 km N



Source: PBL

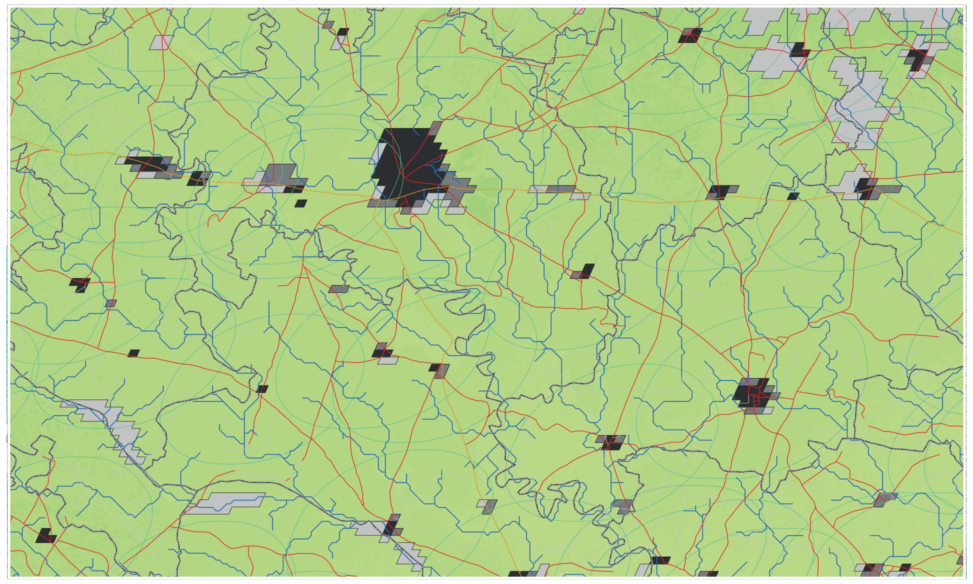
elevation map

legend

height

-428 m +8790 m

0 25 km N



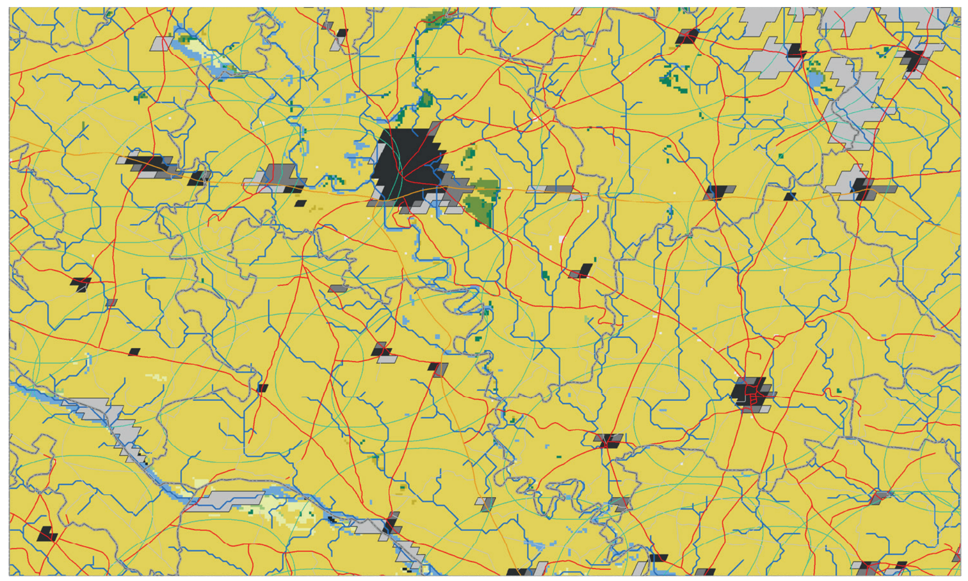
Source: PBL

land-use

legend

- water
- urban area in 1990
- urban area in 2000
- urban area in 2015
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

0 25 km N



Source: PBL

Gorakhpur's use of nature-based solutions for adaptation offers lessons for cities around the world. To scale the type of action happening in Gorakhpur, cities, regional authorities and national governments must strengthen all urban areas adaptive capacities through deeper understanding, better planning and effective finance according to Du (2019).

As a project that started in 2012 and was completed in 2018, the PUA, adopted as a strategy in the flood-prone areas of Gorakhpur, is serving as a means to keep the areas that are vulnerable to flooding, free from construction. Their natural functions (enhancing water storage and infiltration; reducing run-off) are being maintained and are already resulting in fewer floods and reduced impacts of high rainfall.

On the other hand, it has worked in reducing vulnerabilities of the small and marginal farmers and enhanced their coping capacity to deal with impacts of floods. The average agricultural income of model farmers has more than doubled due to reduced input costs, crop diversification, crop intensification, expansion of agricultural land under cultivation, and reduced crop loss due to natural hazards such as floods. Income also increased because of better market linkages and better prices for products.

The successful experiences portrayed by model farmers (Bhatt et.al., 2016) prove that peri-urban farming can be remunerative making their livelihoods profitable and resilient. But specially, what we can learn from them is the crucial importance of farmer to farmer cooperation, and the spread of good practices by the example, upscaling the protection of small patches of land to an increasing network of them, acting as a system of prosperous land for their land managers (the farmers) and an effective buffer to floods.

The adaptive capacity of the farmers has been increased by increasing the transparency of institutions, and by the formation of platforms supporting a new type of agricultural training, strengthening the social cohesion among farmers and community empowerment to maximise their incomes while benefiting the larger self.

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4.4.2
Water Scarcity & Flash Floods
Wadi Restoration

Mersa Matruh, Egypt

Aesthetic view of Wadi Kharouba overlooking the Mediterranean sea in the background
Source: Pascal Bonnet, V. A.-K.-F.-P. (2014)

context reading
the shaping of the risk

spatial context
(custom)

geographical positioning

Arid climate

TPI= U→

socio/spatial & technical configuration

land use system:
agricultural and rural land

population growth rate:
decreasing

urban growth:
non-existent

illegal settlements:
-

level of informality:
-

water technology in place
prehistoric abandoned cisterns and harvesting structures

main water challenge
(adapted from PBL, 2018 & WWDR, 2018)

too little

drought mitigation

water food and production

too polluted

water purification

erosion control

biological control

water temperature control

too much

riverine flood control

urban stormwater runoff

coastal flood

context reading
instruments to deal with the risk

adaptation typology
(IPCC, 2003)

spatial

Open Space

Natural buffers:
Wadis

institutional

National Economic Resources
- low

Equity
- Income inequality: medium
- Community empowerment: low-medium
- Social cohesion: high

Information & Skills:
traditional knowledge

Institutions
- Institutional coordination: low
- Policy coherence
- Transparency

Infrastructure
- Protection standards

Technology penetration

NBS
main aim

Restoration of Wadi areas for agricultural production, water retention, prevention of flash floods and improvement of local livelihoods

implementation
of the NBS

(custom)

sphere of implementation
- physical intervention
- community practices
- policy guidelines

scale of implementation
- urban / peri-urban scale
- basin scale

addressed ecosystem
- point
- corridor
- patch
- network
- matrix

type of cooperation
- household
- community
- municipal
- intermunicipal
- national
- international

type of capital
- social capital
- debt conversion

impact
principles & co-benefits

(SDGs)

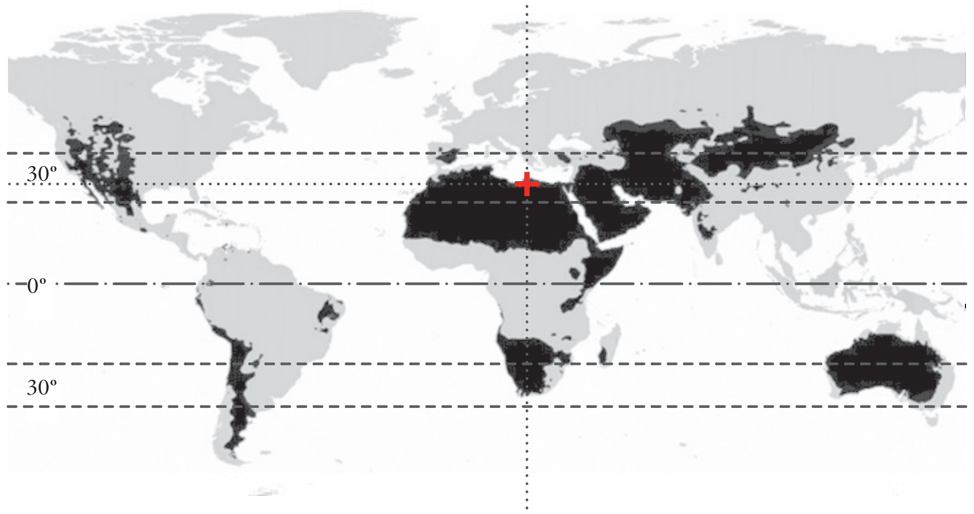
1. No poverty
2. Zero hunger
3. Good health and well-being
4. Quality education
5. Gender equality
6. Clean water and sanitation
7. Affordable and clean energy
8. Decent work and economic growth
9. Industry, innovation and infrastructure
10. Reduced inequalities
11. Sustainable cities and communities
12. Responsible consumption and production
13. Climate action
14. Life below water
15. Life on land
16. Peace, justice and strong institutions
17. Partnerships for the goals

Context reading to water-related challenge

Water scarcity

geographical positioning

■ Arid climate
P.D = Monsoon distribution
A.P = 140 mm / year
T.P.I = U →



socio/spatial & technical configuration

land use system:
potential agricultural and rural land

population growth rate:

type of urban growth:
non-existent

level of informality:

water technology in place:
prehistoric abandoned cisterns and harvesting structures

adaptation typology

Natural buffers
wadis

National economic resources

income inequality

community empowerment

social cohesion

information & skills

institutional coordination

keywords

fluctuating hydrology
gully erosion
flash floods
wadi agriculture abandonment

the shaping of the water-related challenge

The arid and desertic climatic conditions of the Marsa Matrouh characterise a land poor in water resources and soil, with hot and dry summers and mild winters and an average annual rainfall varying around 140 mm/year concentrated in torrential rainfall patterns causing flash floods in built up areas.

Given the scarcity of water and the poor quantity and quality of soils, inhabitants of these lands have developed water and soil harvesting techniques along wadis or dryland rivers -rainfall pathways carved in the landscape- where agriculture can be developed. Wadi-bed are constituted by alluvial deposits, making the soil suitable for cultivation and constituting a subsidiary aquifer of resourceful potential. Prehistorically inhabited by Bronze Age and Graeco-Roman civilizations, the wadis were characterised by its agricultural productivity and richness, where people living here would be prepared for drought and torrential rainfalls patterns.

However, today the state of abandonment of these areas is very much interrelated with heavy gully erosion of the land which is less and less able to retain water during torrential rains. As a result, flash floods are more intense, impacting an increasing number of built up areas downstream.

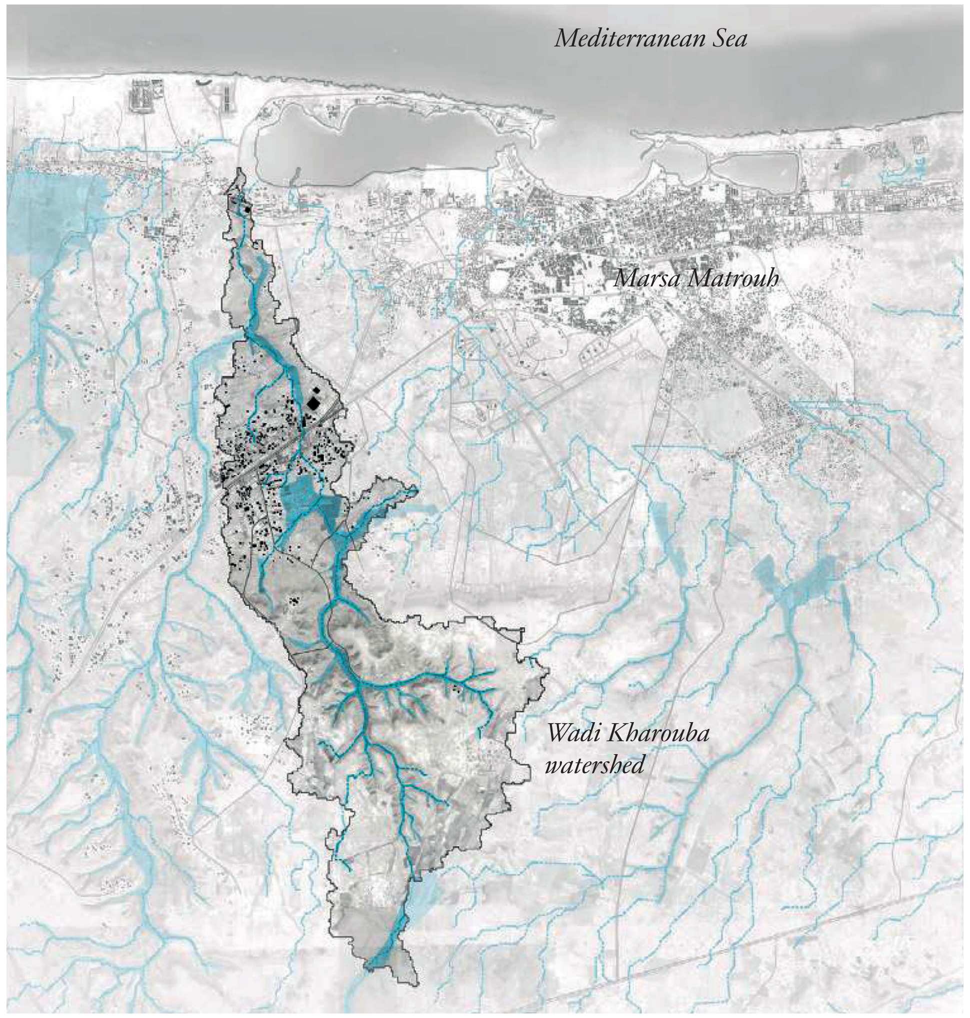
legend

land use (above)
- urban
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

spatial parameters:
- built up areas
- seasonal stream
- water basin
- wadi
- topography

processes:
-abandonment
-gully erosion

water stress:
-flash floods
-water scarcity



Wadi Kharouba watershed. Retrieved from Malek, Y. (2020)

addressed water stress	*main aim NBS*	*scale of implementation*	*addressed ecosystem*	*type of cooperation*	*type of capital*
main: water scarcity cascading: soil erosion, flash floods	-increase water storage capacity -decrease the damage of torrential flash floods downstream -improve livelihoods and socio-economic conditions of Bedouin people	physical intervention - rehabilitation of cisterns - development of dikes and rainwater harvesting structures - reclamation of the wadi-bed for agriculture	local structures: semi-circular bunds and sub-surface cisterns regional system: wadi reclamation	World Bank & the Egyptian government Mediterranean Agronomic Institute of Bari (CIHEAM) & Ministry of Agriculture, Desert Research Center (DRC) of Marsa Matrouh in Egypt Implementing agencies & Bedouin people	financial - private funding (debt conversion)

sphere of implementation

The Wadi Restoration includes two levels of implementation: the fist one in the shape of international programs and development projects, and the second one is the landing of these projects in physical interventions.

The Matrouh Resources Management Project (MRMP) and Matrouh Rural Sustainable Development Project and Alternatives (MARSADEV) are the main projects and include: the rehabilitation of cisterns, development of dikes and rainwater harvesting structures, and the reclamation of the wadi.

scale of the implementation & addressed ecosystem

The Wadi corridor is the addressed ecosystem, however in order to deliver its restoration a series of interventions take place at different scales:

At a Macro watershed level, the Flash Flood Hazards are addresed through the construction of dikes across the wadis, slowing down the water flow but also helping retain water and soil formation. These dikes are as well the basis for the terraced agricultural lands within the wadi.
At a Macro watershed level, the construction of sub-surface cisterns recharge the groundwater system, supporting the long-term availability of water resources for irrigation
At a Micro watershed level or local level, the semi-circular bunds create shadow conditions and harvest wind, creating optimum conditions for the development of localized growing of plants for cultivation.

type of cooperation

The type of cooperation in the Wadi Kharouba restoration project is top-down, where the funding and implementation takes place on a central governmental level. The relation with the Bedouin people inhabiting the area is of consultation and support, however not of co-creation. The developed project is then "hand in" to the Bedouin families so they can work the lands in the long term.

World Bank & the Egyptian government
As the main financing entities in a collaboration project

Mediterranean Agronomic Institute of Bari (CIHEAM) & Ministry of Agriculture, Desert Research Center (DRC) of Marsa Matrouh in Egypt
As the main implementing agencies

Implementing agencies & Bedouin people
The implementing agencies stablish a relation with the Bedouin people to have their backing and support, but also to learn from the local and traditional knowledge on the site conditions influencing the harvesting of wind, soil and water.

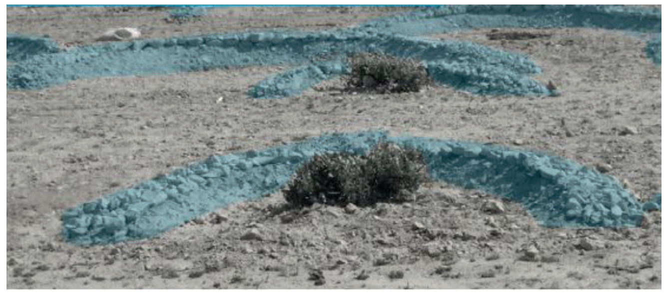
type of capital

The type of capital is monetary, in the form of debt conversion with a budget of 1,5 million EUR. In this sense, the fixed external injection of money is invested in one singular project and as Henk Ovink says in the Climate Adaptation Summit 2021 "River and Deltas of Tomorrow", finance from a single point perspective gives only short term gains.


Dike construction. Retrieved from Malek, Y. (2020)


Reclamation of Wadi-bed. Retrieved from Malek, Y. (2020)


Terraces agricultural lands. Retrieved from Malek, Y. (2020)


Semi-circular bunds. Retrieved from Malek, Y. (2020)


Sub-surface cisterns. Retrieved from Malek, Y. (2020)


Sub-surface cisterns. Retrieved from Malek, Y. (2020)

NBS principles
(extrapolated from Cohen et.al., 2019)

NbS1.- Conservation
The wadi restoration enhances natural habitat for diverse groups of plants and animals

NbS2.- Synergies
An array of synergies arise from the wadi restoration:
- they serve as hydrological corridors and water source in arid and semi-arid regions
- they serve as the base for agricultural economies
- they can serves as the backbone for urban development

NbS3.- Site specific context
This strategy is specific to the wind directions, rainfall patterns, topography and knowledge of the site

NbS4.- Transparency & broad participation
-

NbS5.- Diversity & involvement over time
-

NbS6.- Landscape scale
The strategy is implemented at a macro watershed scale, aiming at restoring the wadi corridor as a system benefiting local livelihoods on site and reducing flash flood events downstream.

NbS7.- Trade-offs
-

NbS8.- Policy integration
-

synergies / trade-offs
(extrapolated from literature review)

environmental synergies / trade-offs
- Preservation of local biodiversity

social synergies / trade-offs
- Food security
- Livelihoods of Bedouins

economic synergies / trade-offs
- Sustained agricultures in time
- Long-term savings in flood damages
- Tourism attraction on the restored hydraulic structures

SDGs
(extrapolated from synergies)

1 No poverty
2 Zero hunger
3 Good health and well-being
4 Quality education
5 Gender equality
6 Clean water and sanitation
7 Affordable and clean energy
8 Decent work and economic growth
9 Industry, innovation and infrastructure
10 Reduced inequalities
11 Sustainable cities and communities
12 Responsible consumption and production
13 Climate action
14 Life below water
15 Life on land
16 Peace, justice and strong institutions
17 Partnerships for the goals

Mapping set
Tana Watershed, Kenya

basemap

legend

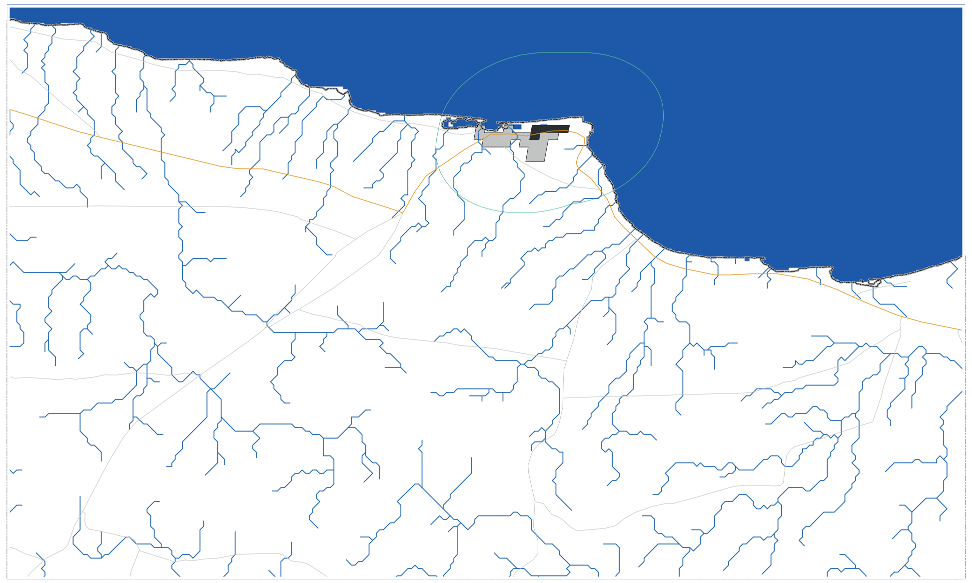
- administrative boundary

roads
- highway
- fast transit road
- regional road
- main road
- local road

water
- water body
- river

urban area
- urban area in 1990
- urban area in 2000
- urban area in 2015
- 10 km around urban area in 1990

0 25 km N



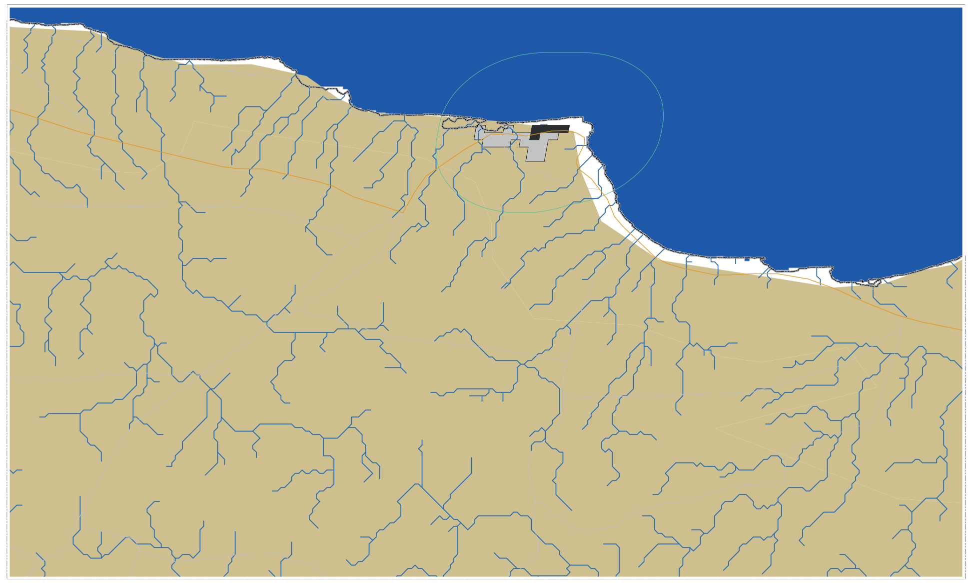
Source: PBL

soil map

legend

- Acrisols
- Cambrisols
- Chernozems
- Podzoluvisols
- Rendzinas
- Ferrasols
- Gleysols
- Phaeozems
- Lithosols
- Fluvisols
- Kastanozems
- Luvisols
- Greyzems
- Nitosols
- Histosols
- Podzols
- Arenosols
- Regosols
- Solonetz
- Andosols
- Rankers
- Vertisols
- Planosols
- Xerosols
- Yermosols
- Solonchaks
- S2-3a
- W2-a

0 25 km N



Source: PBL

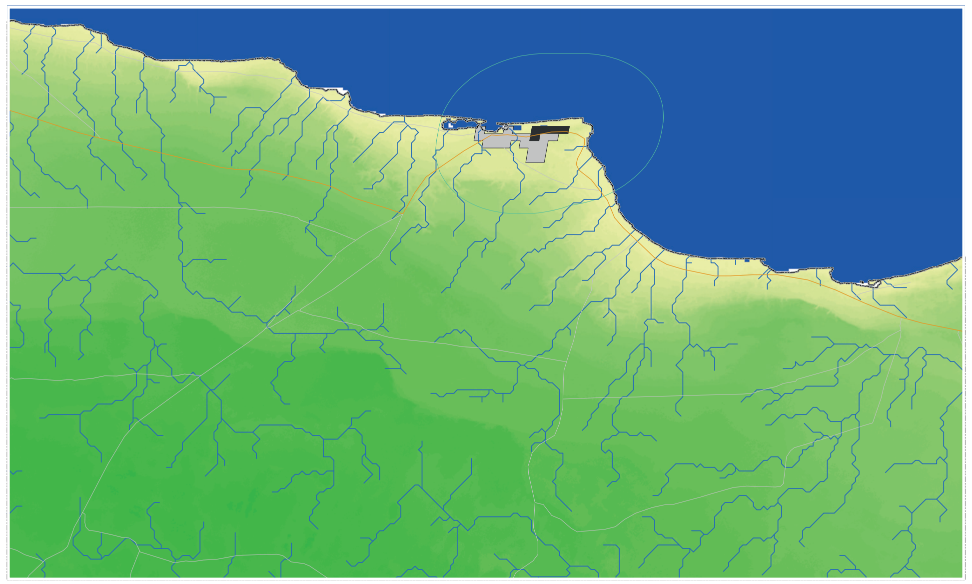
elevation map

legend

height

-428 m +8790 m

0 25 km N



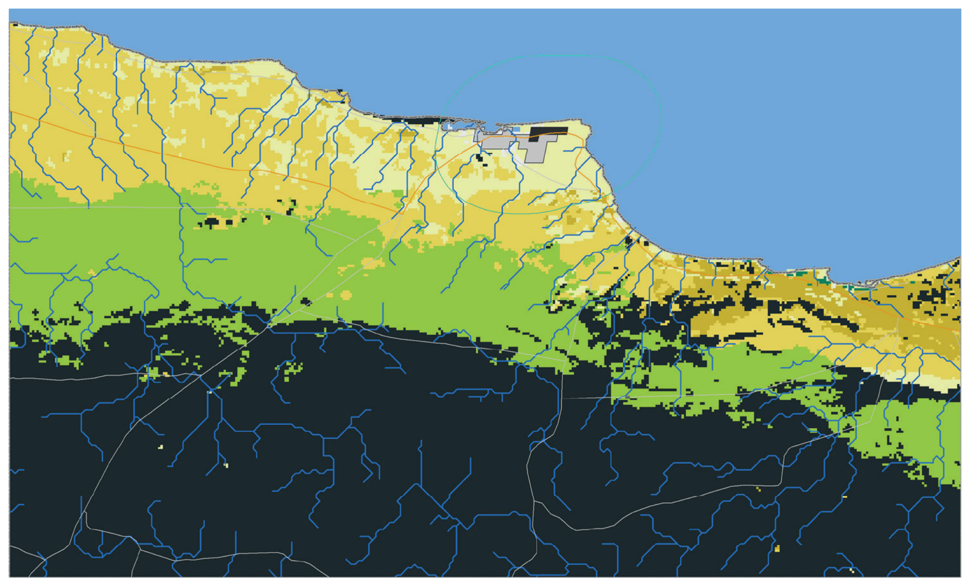
Source: PBL

land-use

legend

- water
- urban area in 1990
- urban area in 2000
- urban area in 2015
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

0 25 km N



Source: PBL

Wadi restoration projects can harvest water and allow crop growth, enhancing an agricultural ecosystem within the desert (Cappola et.al., 2019 and Rieger, 2019). However, as (Cappola et. al., 2019) reflects, it is a fragile ecosystem that depends on a continued maintenance and management of water harvesting structures ensuring water availability through the year.

In this sense, the scalability and replicability of this NBS, is dependent on the development of a model that ensures the management and maintenance of the fragile ecosystem. In this case, the lack of community inclusion in the assessment, design, implementation and maintenance of the NBS together with the type of capital as debt conversion, put in question the replicability and evolution in time of the proposal.

As Henk Ovink poses in the Climate Adaptation Summit 2021 "River and Deltas of Tomorrow", finance from a single point perspective gives only short-term gains, fact that is reflected in the low score of SDGs.

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4.4.3
Upper Tana-Nairobi Water Fund

Tana-Nairobi, Kenya

Anna and Joseph Gatheru's farm.
Source: The Nature Conservancy; Photo: Roshni Lodhia

context reading
the shaping of the risk

spatial context
(custom)

geographical positioning

Subtropical climate

TPI= U ↘

socio/spatial & technical configuration

land use system:
Peri-urban agricultures

population growth rate:
medium

urban growth:
land use change from forest to agricultural land

illegal settlements:
low - medium - high

level of informality:
high

water technology in place
partial water supply
partial sewage system
hydropower facilities

main water challenge
(adapted from PBL, 2018 & WWDR, 2018)

too little

drought mitigation

water food and production

too polluted

water purification

erosion control

biological control

water temperature control

too much

riverine flood control

urban stormwater runoff

coastal flood

context reading
instruments to deal with risk

adaptation typology
(IPCC, 2003)

spatial

Open Space
Buffer areas:
re-naturalization of hillsides and riparian vegetation.

institutional

Economic Resources
- Tana-Nairobi Water Fund

Equity
- Income inequality: medium
- Community empowerment: medium-low
- Social cohesion: medium

Information & Skills

Institutions
- Institutional coordination: high
- Policy coherence
- Transparency

Infrastructure
- Protection standards
- Operation standards

Technology penetration

NBS
main aim

Restore natural areas upstream in order to increase downstream water quality, quantity and reliability and along the watershed.

implementation
of the NBS

(custom)

sphere of implementation
- physical intervention
- community practices
- policy guidelines

scale of implementation
- urban / peri-urban scale
- basin scale

addressed ecosystem
- point
- corridor
- patch
- network
- matrix

type of cooperation
- household
- community
- municipal
- intermunicipal
- national
- international

type of investment
- public
- private

impact
principles & co-benefits

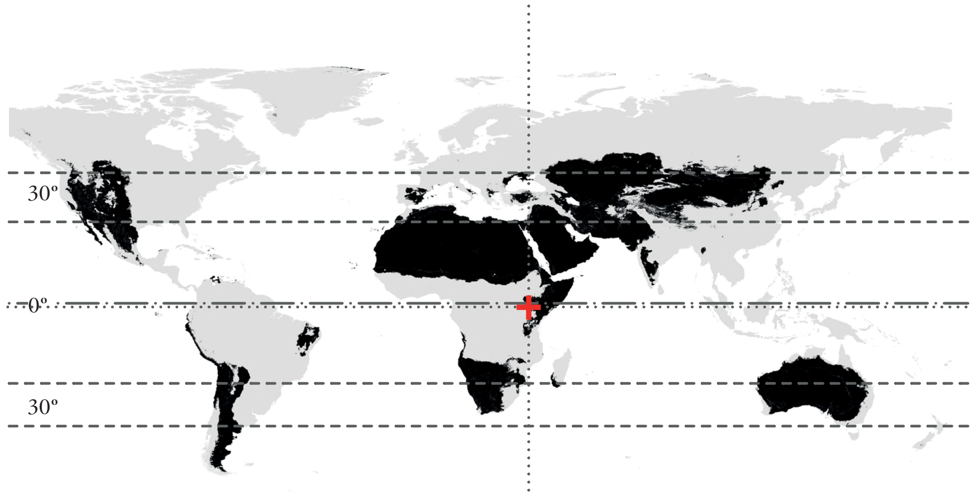
(SDGs)

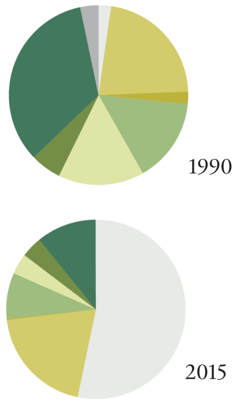
1. No poverty
2. Zero hunger
3. Good health and well-being
4. Quality education
5. Gender equality
6. Clean water and sanitation
7. Affordable and clean energy
8. Decent work and economic growth
9. Industry, innovation and infrastructure
10. Reduced inequalities
11. Sustainable cities and communities
12. Responsible consumption and production
13. Climate action
14. Life below water
15. Life on land
16. Peace, justice and strong institutions
17. Partnerships for the goals

Context reading to water stress
Lack of reliable water supply

geographical positioning

■ Subtropical climate
P.D = Monsoon distribution
A.P = 610 mm / year
T.P.I = U ↘





socio/spatial & technical configuration

land use system:
Peri-urban agriculture

population growth rate:

type of urban growth:
unplanned

level of informality:

water technology in place:
non-existent sewer system in peri-urban areas

adaptation typology

Natural buffers
Peri-Urban Agricultural Floodplain

National economic resources

income inequality

community empowerment

social cohesion

information & skills

institutional coordination

keywords

Subtropical climate
Water quality
Water availability
Sedimentation
Land use and management
Degradation of water bodies

the shaping of the water stress

The Tana River is one of the most important rivers in Kenya, suppling 95 percent of Nairobi's clean water, with approximately 4 million residents, and to another 5 million people living in the watershed. The river watershed is also the country's most important agricultural areas and is also responsible for 50 percent of the country's hydropower output. With Nairobi contributing 60 percent of the country's GDP, the Tana River can be considered the key driver fuelling Kenya's economic growth.

Since the 1970s, the hillsides of the Tana Basin as well as wetland areas have been converted to agricultural land, which has had a direct impact on the quality of the water downstream. The removal of natural areas, which typically retain water allowing for a more careful filtration, has caused increased sedimentation in the Tana River and also reduced farmland productivity since nutrients are washed away easily. The increased sedimentation can also compromise water treatment and distribution facilities as well as hydropower production. In many instances increased sedimentation has caused complete service disruptions for days or weeks at a time. Today, 60 percent of Nairobi's residents do not have access to a reliable water supply.

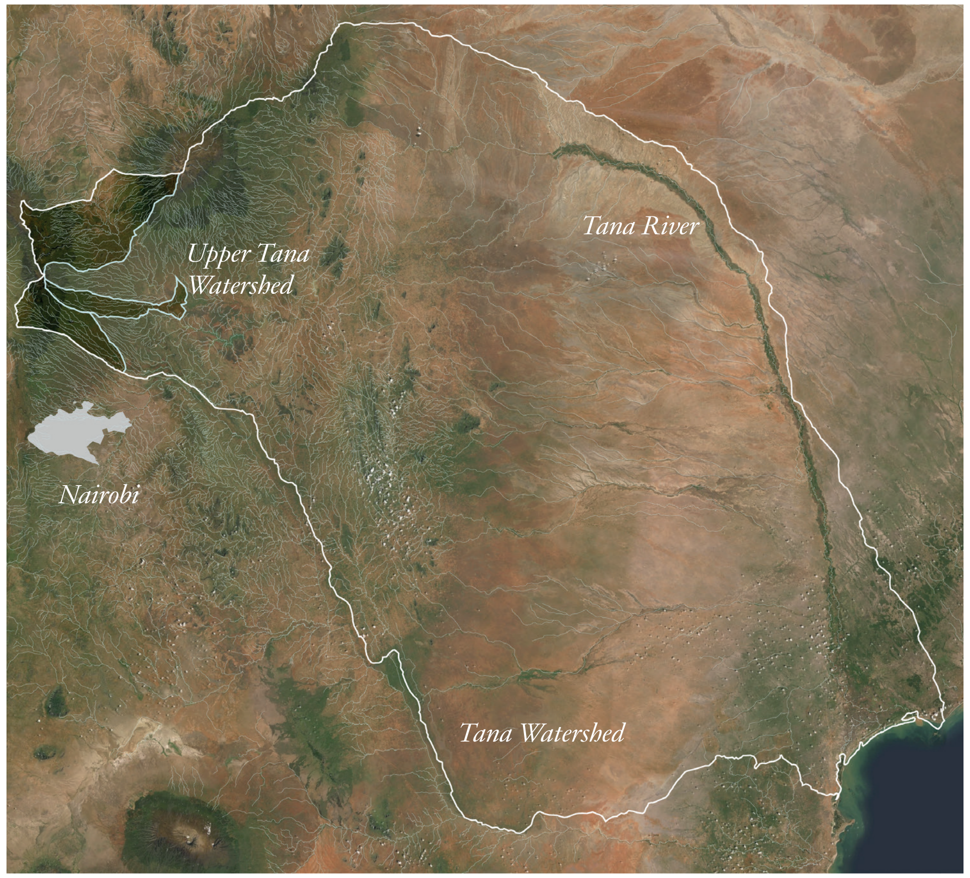
legend

land use (above)
- urban
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

spatial parameters:
- urban area
- agricultural land
- forest / natural land
- water streams
- watershed

processes:
-land use change:
forest to agricultural land
-increased sedimentation

water stress:
-lack of reliable water supply



addressed water stress

main: Water Quality
cascading: Water supply and pollution

main aim NBS

Restore natural areas upstream in order to increase downstream water quality, quantity and reliability and along the watershed.

scale of implementation

<u>physical intervention</u>
- Vegetation buffer zones along riverbanks
- Agroforestry practices
- Terracing steep and very steep farmlands
- Reforestation of degraded lands and forest edges
- Grass buffer strips in farmlands
- Mitigation of erosion from dirt roads

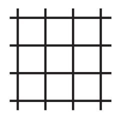
<u>policy guidelines</u>
- Definition of protection sites and delineation of river margin land use
- Land use change or alteration incorporating better ecologically friendly practices.

<u>community practices</u>
- Provision of training, resources and equipment for key upstream stakeholders to better manage land and water resources.

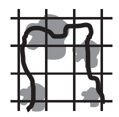
addressed ecosystem

Tana River

Farmlands



Thika-Chania, Maragua and Sagana-Gura sub-watersheds



Tana Watershed

type of cooperation

Local community management and implementation groups

Public-private Steering Committee.: Nairobi City Water and Sewage Company (NCWSC); Kenya Energy Generation (KenGen); Water Resources Management Authority (WRMA); Tana and Athi Rivers Development Authority (TARDA); East African Breweries, Coca-Cola, Frigoken Horticulture, and the water technology company Pentair.

Scientific support by the International Centre for Tropical Agriculture (CIAT) and The Nature Conservancy (TNC).

International support from the Swedish International Development Agency (SIDA), Global Environment Facility (GEF), United Nations Environment Program (UNEP), International Fund for Agricultural Development (IFAD), and Coca-Cola.

type of capital

<u>financial</u>
Hybrid Trust Fund, consisting of an endowment and a revolving fund to ensure sustainability and continuity of watershed investments and registered as a charitable with the sole purpose of funding soil and water conservation activities within the Upper Tana watershed.

sphere of implementation

The Tana-Nairobi Water Fund was set up on a governance level, with a public-private steering committee formed by multiple stakeholders. This committee deliberated on the necessary studies that would inform policy implementation and site targeted interventions which would restore the watershed.

Working with key management, governance and implementation stakeholders, the Public-private Steering Committee for the water fund can manage and deliberate on the necessary allocation of funds for projects on ground which increase water quality and availability as well as support local farmers funding and providing skills, training and resources needed to better manage their land, conserve water, reduce runoff and improve productivity.

addressed ecosystem

The Tana River is Kenya's longest river, stretching almost 1,000 km from the edge of the Great Rift Valley to the fertile delta where it meets the Indian Ocean. The upper basin covers approximately 17,000 km2 with about 5.3 million inhabitants. It includes two of Kenya's 'water towers': the Aberdare Mountains and Mount Kenya. The river also sustains important aquatic biodiversity and drives agricultural activities that feed millions of Kenyans. The upper reaches of the source mountains themselves lie largely within protected areas; however just downstream, the river is being impacted by sediments, and dry season flows are being depleted.

The Tana-Nairobi Water Fund has prioritized three sub-watersheds: Thika-Chania, Maragua and Sagana-Gura, based on strategic parameters and systems for the Tana-Nairobi region. Millions of people and the iconic wildlife that depend on the river bear the brunt of these impacts. These problems are amplified by the expected impacts of climate change including less water in the dry season and increased sediment loads during severe rainfalls.

type of cooperation

The Nature Conservancy has been a key player in gathering the water fund partners. Partners contributing to/supporting the Upper Tana Nairobi Water Fund (UTNWF) have different roles to play; mainly steering committee partners who provide the guidance on goals and aims of the project, local implementation partners who oversee the conservation activities in the catchment and water fund supporting partners (donors). The water fund partners form the governance mechanism driving the water fund forward, with a focus on improving farming activities.

The UTNWF also brings together major water consumers in Nairobi – companies and government agencies interested in high quality and reliable water supply – and creates linkages to non-urban communities.

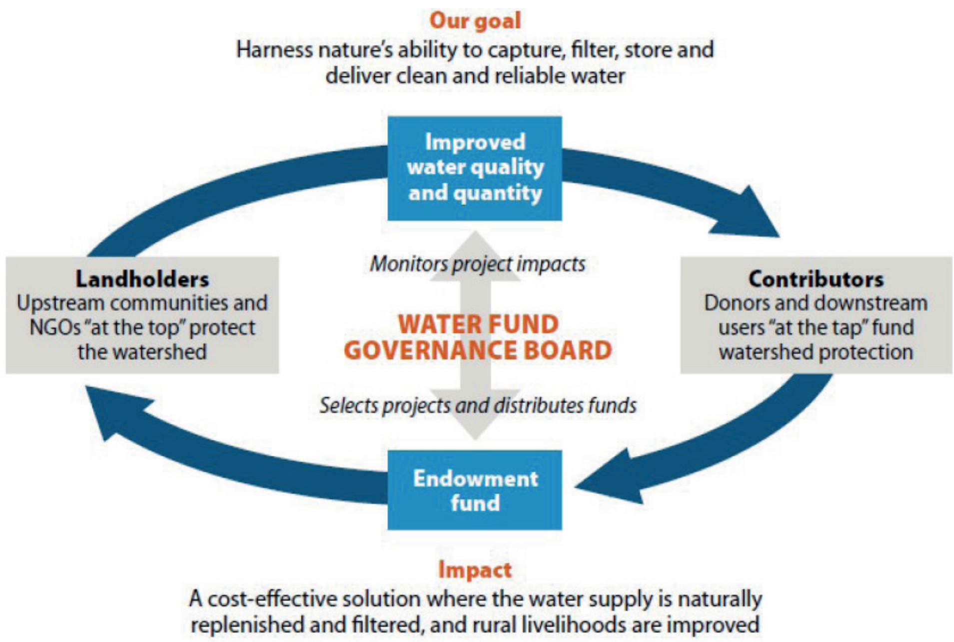
Major water consumers are largely playing the role of investors, including supporting endowments for the UTNWF, while non-urban and farmer communities are provided with training and incentives to support land conservation measures, preventing water pollution, silting and deforestation. The Kenyan government joining in the effort, committed a substantial amount of money to the establishment of the UTNWF, reflecting high level commitment to the restoration and conservation of the Tana River.

type of investment

The Upper Tana-Nairobi Water Fund builds on the Nature Conservancy's experience addressing similar issues in Latin America, where more than 30 water funds are either underway or in development. This fund is the first of its kind in Africa. Public and private donors and major water consumers downstream contribute to the Fund to support upstream water and soil conservation measures, resulting in improved water quality and supply.

The Steering Committee agreed that a Trust registered under Kenyan law as a charitable organisation and governed by a Board of Trustees was the preferred organisational structure.

It has a "Hybrid Fund" financial structure, incorporating both Endowment Fund structure – whose capital is invested in order to generate a steady annual stream of income. Only the investment interest and earnings are spent, while the principal is either maintained or increased; and Revolving Fund—a fund that periodically (e.g., annually) is replenished through fees collected and/or through donor contributions. The 'Hybrid Fund' financial structure was considered by the Steering Committee the best way to ensure sustainability and continuity of watershed investments.



The Water Fund Concept, TNC (2017).

NBS principles
(extrapolated from Cohen et.al., 2019)

NbS1.- Conservation
The UTNWF is conceptualized with conservation of watershed sources as the prime goal in order to guarantee water security and quality throughout the watershed. For this, projects and natural reservations which secure natural vegetation are prioritized. Land conservation measures were carried out on areas representing 8% of the three priority sub-watersheds. Some initiatives include: Vegetation buffer zones along riverbanks; Agroforestry; Terracing of steep and very steep farmlands; Reforestation for degraded lands at forest edges; Grass buffer strips in farmlands; and Mitigation of erosion from dirt roads.

NbS2.- Synergies
Given the various NBS employed at different scales and according to site specific conditions, ecological trade-offs are guaranteed and are encouraged to happen. Local stakeholders' involvement and engagement are primordial for the success of the project. To list a few: Increased farming yields enhancing income, greater employment opportunities, additional animal fodder, avoided electricity costs due to more efficient hydropower production, greater clean water revenue, reduced sedimentation within urban water and sewage infrastructure, and overall cleaner drinking water.

NbS3.- Site specific context
The UTNWF supports projects according to specific modelling designs of the issues encountered vs. how much return and benefits would these generate using RIOS and ROI methodologies.

NbS4.- Transparency & broad participation
Given the multi-stakeholder and public-private investment nature of the Fund, it is governed by a Board of Trustees, which manage the overall Water Fund operations and comprise 9 to 15 representatives from the major stakeholders of the Water Fund. It has a set of committees as well as a Technical Secretariat, responsible for implementing the decisions and policies of the board and responsible for the day-to-day management of the Water Fund activities. In this way, the fund's investments are always accountable to the contributing stakeholders.

NbS5.- Ecosystem diversity & evolution over time
For the overall success of projects, careful consideration is taken when studying the natural and ecosystem characteristics throughout the Tana Watershed. In this way, an alignment between Nature based Solutions and site and systemic particularities are achieved. The Water Fund, has focused on 3 sub-watersheds (Thika-Chania, Maragua and Sagana-Gura) based on critical aspects which could kickstart the programme. The same model design can be implemented in the remaining sub-watersheds in order to maximize the restoration of the Tana-Nairobi Watershed. The Fund model is also a valid case study for replication in other watersheds throughout Africa which face similar water scarcity and quality issues.

NbS6.- Landscape scale
Given the scale of the water issue addressed by the UTNWF, only at the watershed level can the water availability and quality necessary for secure water provision be achieved throughout the basin, from rural to urban.

NbS7.- Trade-offs
Dependent on continuous volume of funding for implementation phases. Success is dependent on a unified effort of conservation and sustainable practices upstream from communities and farmers. Farmers and communities which are not contemplated in the watersheds can fall into disadvantage since these will not receive funds and other benefits from the water fund committee. The specific practices to be implemented along the basin can force farmers which do not conform to the required changes to resist transitioning.

NbS8.- Policy integration
The Public-private design encompassing multi-scalar stakeholders has allowed for a more tuned and grounded advice for policies on conservation and community engagement.

synergies / trade-offs
(provided by the study)

environmental synergies / trade-offs
- Increasing vegetation buffers will create new habitat for pollinators and seed dispersal agents.
- Over 100,000 new trees will be planted as part of Water Fund conservation interventions, creating a substantial carbon sink for the environment.

social synergies / trade-offs
- A reduction in reservoir sedimentation will lead to a greater ability to manage flows and water balance within the Seven Forks Cascade to maximise power generation.
- Avoided interruptions in electricity generation.
- Reduction in sediment being carried into streams will have some positive effect on health outcomes.
- Conservation interventions in the watershed will improve water quality, benefitting approximately half a million residents outside Nairobi who do not have access to treated water.
- Improved water quality is also likely to reduce costs for those who engage in home treatment and to provide health benefits for those who do not.

economic synergies / trade-offs
- Good water supply to urban-based private sector processers, including bottling plants, is crucial for quality employment, a growing economy, and a sustained source of foreign exchange for the country.
- Reduction in Sludge intake in water treatment plants reduce operation costs.
- Reduction in water supply interruptions.
- Increased yields for farmers mean more profits for rural communities.
- As much as 10,000 employment posts per year in rural areas.

SDGs
(extrapolated from synergies)

1 No poverty
2 Zero hunger
3 Good health and well-being
4 Quality education
5 Gender equality
6 Clean water and sanitation
7 Affordable and clean energy
8 Decent work and economic growth
9 Industry, innovation and infrastructure
10 Reduced inequalities
11 Sustainable cities and communities
12 Responsible consumption and production
13 Climate action
14 Life below water
15 Life on land
16 Peace, justice and strong institutions
17 Partnerships for the goals

Mapping set
Tana Watershed, Kenya

basemap

legend

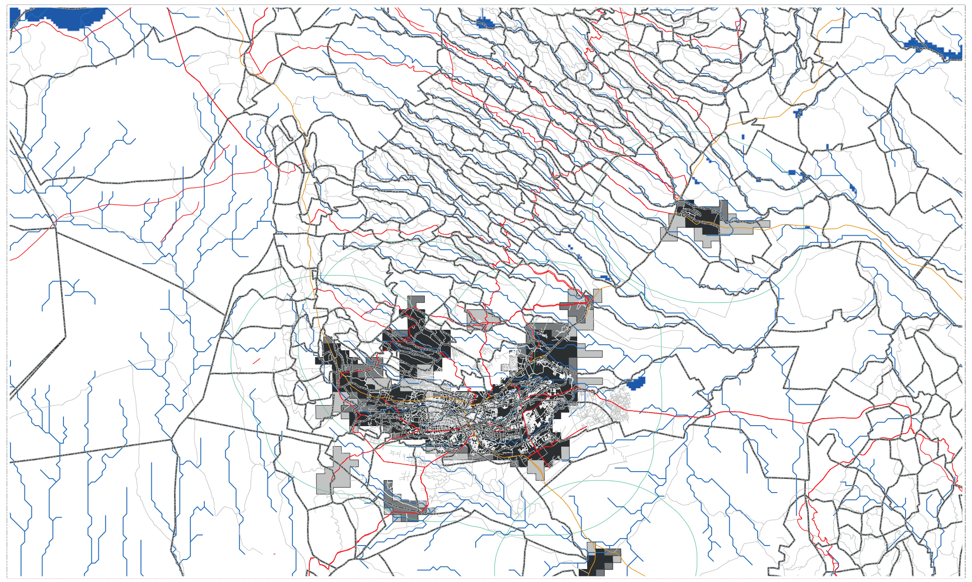
- administrative boundary

roads
- highway
- fast transit road
- regional road
- main road
- local road

water
- water body
- river

urban area
- urban area in 1990
- urban area in 2000
- urban area in 2015
- 10 km around urban area in 1990

0 25 km N



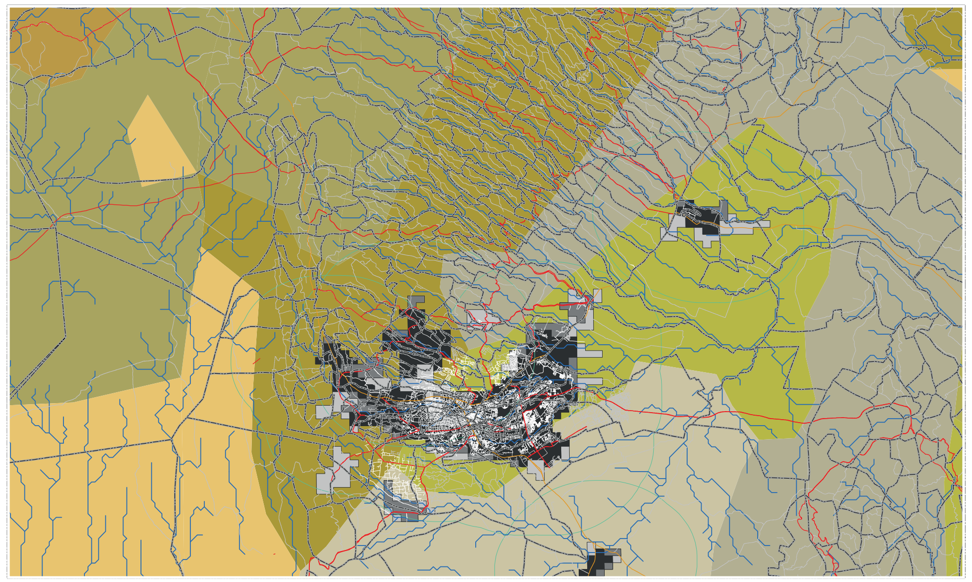
Source: PBL

soil map

legend

- Acrisols
- Cambrisols
- Chernozems
- Podzoluvisols
- Rendzinas
- Ferrasols
- Gleysols
- Phaeozems
- Lithosols
- Fluvisols
- Kastanozems
- Luvisols
- Greyzems
- Nitosols
- Histosols
- Podzols
- Arenosols
- Regosols
- Solonetz
- Andosols
- Rankers
- Vertisols
- Planosols
- Xerosols
- Yermosols
- Solonchaks
- S2-3a
- W2-a

0 25 km N



Source: PBL

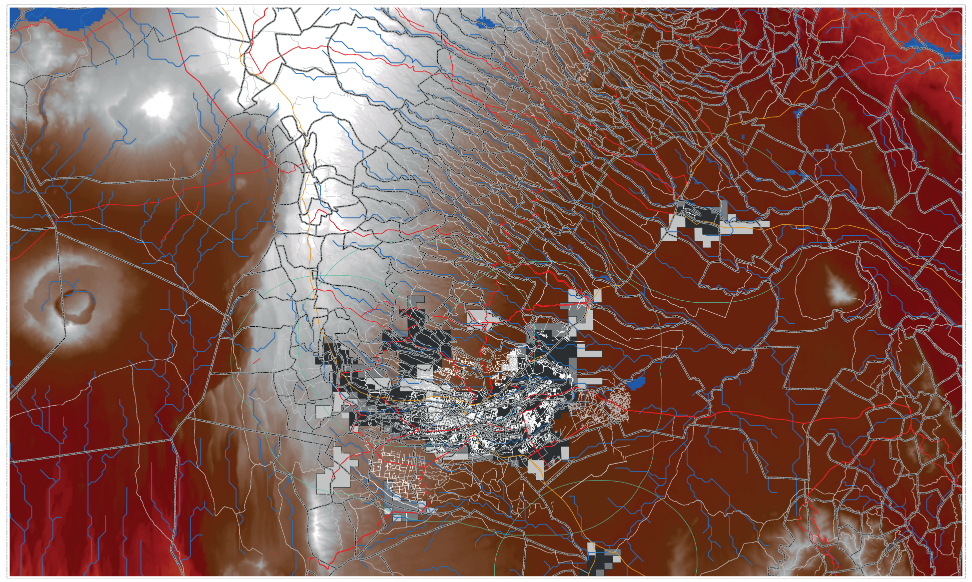
elevation map

legend

height

-428 m +8790 m

0 25 km N



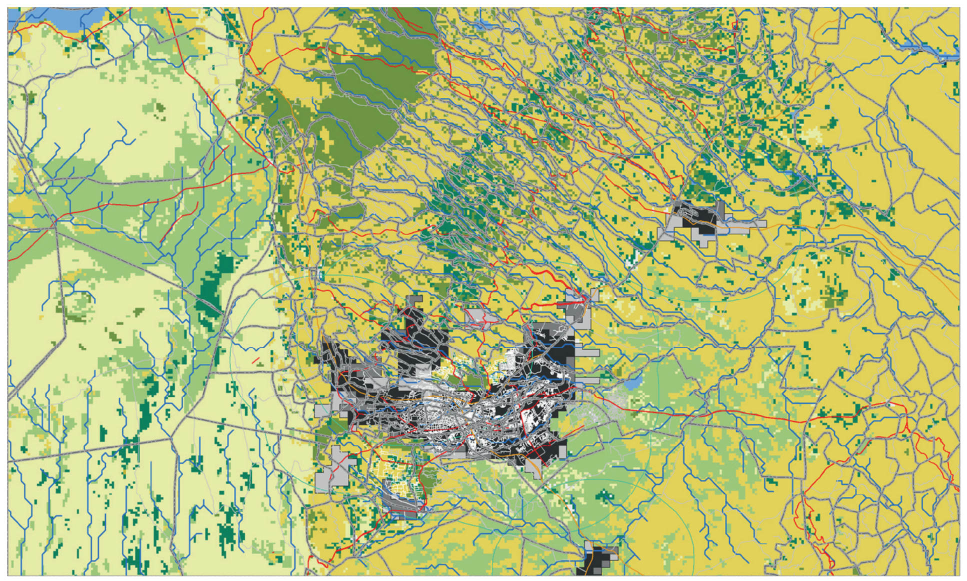
Source: PBL

land-use

legend

- water
- urban area in 1990
- urban area in 2000
- urban area in 2015
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

0 25 km N



Source: PBL

The UTNWF is the first of its kind in Africa, but the model of investment and governance as well as land management and implementation has absolute potential for replication across Africa given the extensive experience of Water Funds already applied in 30 cities around the world by The Nature Conservancy.
In 2016, the city of Cape Town invited TNC to explore establishing a Water Fund and in 2018, Greater Cape Town Water Fund was officially launched.
TNC scientists have already assessed the potential for watershed conservation across 30 large cities in Sub-Saharan Africa that are primarily dependent on surface water supply, which could benefit more than 80 million people.

The successful implementation of the Water Fund as an independent entity depends on expanding public and private financial support. That support must be a mix of funding from major Nairobi water users, who recognise the clear goals behind this effort, and from generous donors with interests in the environment and development sectors given the clear value of the Water Fund to both.

By looking at the watershed scale, a more systemic approach can resolve water issues along the system and allow for solutions to be implemented outside dense urbanized areas, which can prove to be more effective and less costly. The fund manages, reinvests and attracts more and more public and private investments across scales that result in more jobs and projects along the watershed in various sectors. This proves to be an effective economic stimulant in addition to regeneration the basins ecosystem.

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4.4.4
Mangrove Rehabilitation
Building With Nature Indonesia

Semarang, Indonesia

Mangrove rehabilitation in Indonesia (n.d)
Source: Deltares

Identification framework of analysis and design

Summary, Semarang

context reading
the shaping of the risk

spatial context
(custom)

main water challenge
(adapted from PBL, 2018 & WWDR, 2018)

geographical positioning

Tropical climate

TPI= D →

socio/spatial & technical configuration

land use system:
peri-urban agricultures

population growth rate:
high

urban growth:
unplanned

illegal settlements:
medium

level of informality:
high

water technology in place
partial water supply and sewage system

too little

drought mitigation

water food and production

too polluted

water purification

erosion control

biological control

water temperature control

too much

riverine flood control

urban stormwater runoff

coastal flood

context reading
instruments to deal with the risk

adaptation typology
(IPCC, 2003)

spatial

Open Space
Constructed and restored mangrove
Sustainable aquaculture

institutional

Economic Resources

- Indonesian Government
- German Federal Ministry for the Environment, nature Conservation, Building and Nuclear Safety
- Waterloo Foundation

Equity

- Income inequality: medium
- Community empowerment: high
- Social cohesion: medium

Information & Skills

Institutions

- Institutional coordination: medium
- Policy coherence
- Transparency

Infrastructure

- Protection standards
- Operation standards

Technology penetration

NBS
main aim

Constructed permeable water structures, reducing erosion by stimulating mangrove rehabilitation in order to fixate sediment.

implementation
of the NBS

(custom)

sphere of implementation

- physical intervention
- community practices
- policy guidelines

scale of implementation

- urban / peri-urban scale
- basin scale

addressed ecosystem

- point
- corridor
- patch
- network
- matrix

type of cooperation

- household
- community
- municipal
- intermunicipal
- national
- international

type of capital

- Donations
- Government Funding

impact
principles & co-benefits

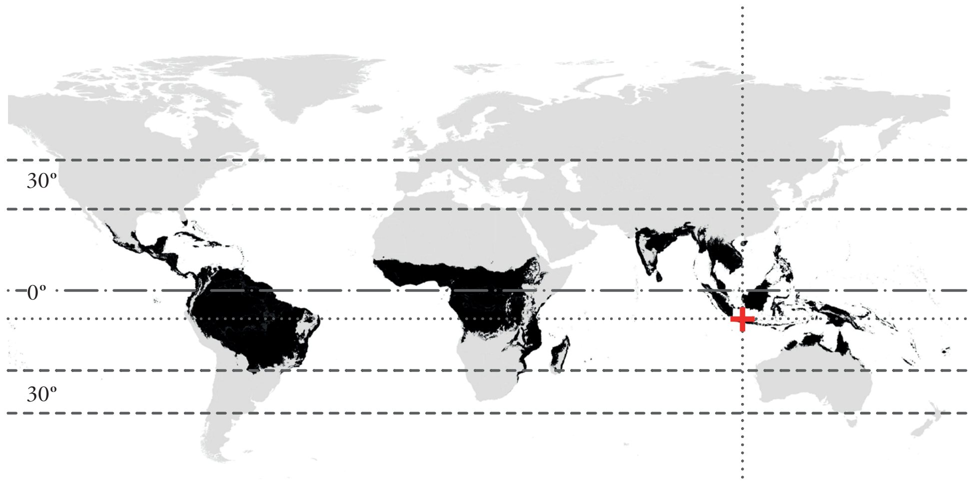
(SDGs)

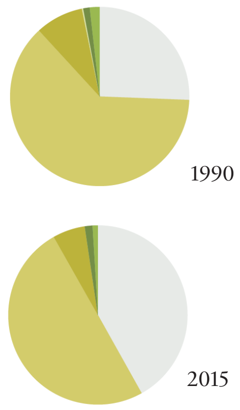
1. No poverty
2. Zero hunger
3. Good health and well-being
4. Quality education
5. Gender equality
6. Clean water and sanitation
7. Affordable and clean energy
8. Decent work and economic growth
9. Industry, innovation and infrastructure
10. Reduced inequalities
11. Sustainable cities and communities
12. Responsible consumption and production
13. Climate action
14. Life below water
15. Life on land
16. Peace, justice and strong institutions
17. Partnerships for the goals

Context reading to water stress
Coastal floods

geographical positioning

■ Tropical climate
P.D = Monsoon distribution
A.P = 2490 mm/year
T.P.I = D →





socio/spatial & technical configuration

land use system:
Peri-urban agriculture

population growth rate:

type of urban growth:
unplanned

level of informality:

water technology in place:
non-existent sewer system in peri-urban areas

adaptation typology

Natural buffers
Mangroves

National economic resources

income inequality

community empowerment

social cohesion

information & skills

institutional coordination

keywords

Coastal erosion
Urban floods
Mangrove loss
Sea level Rise

the shaping of the water stress

In the northern part of Java Island, around 70,000 people are at risk by the sea if erosion is not controlled. Coastal floods in the region are increasing and have destroyed much of the infrastructure as well as productive agricultural land.

The removal of mangrove belt areas for aquaculture development, coastal infrastructures, groundwater extraction causing subsidence and river canalization have all further exacerbated the situation. Many people rely on natural resources related to this biome as income. On top of this, sea level rise is projected to flood 6 kilometers in land by 2100, affecting an estimate of 30 million people.

In this sense, both geographic and socio-spatial trends are shaping coastal floods within the city of Semarang and its peri-urban areas, agricultural land and sub-districts (Demak).

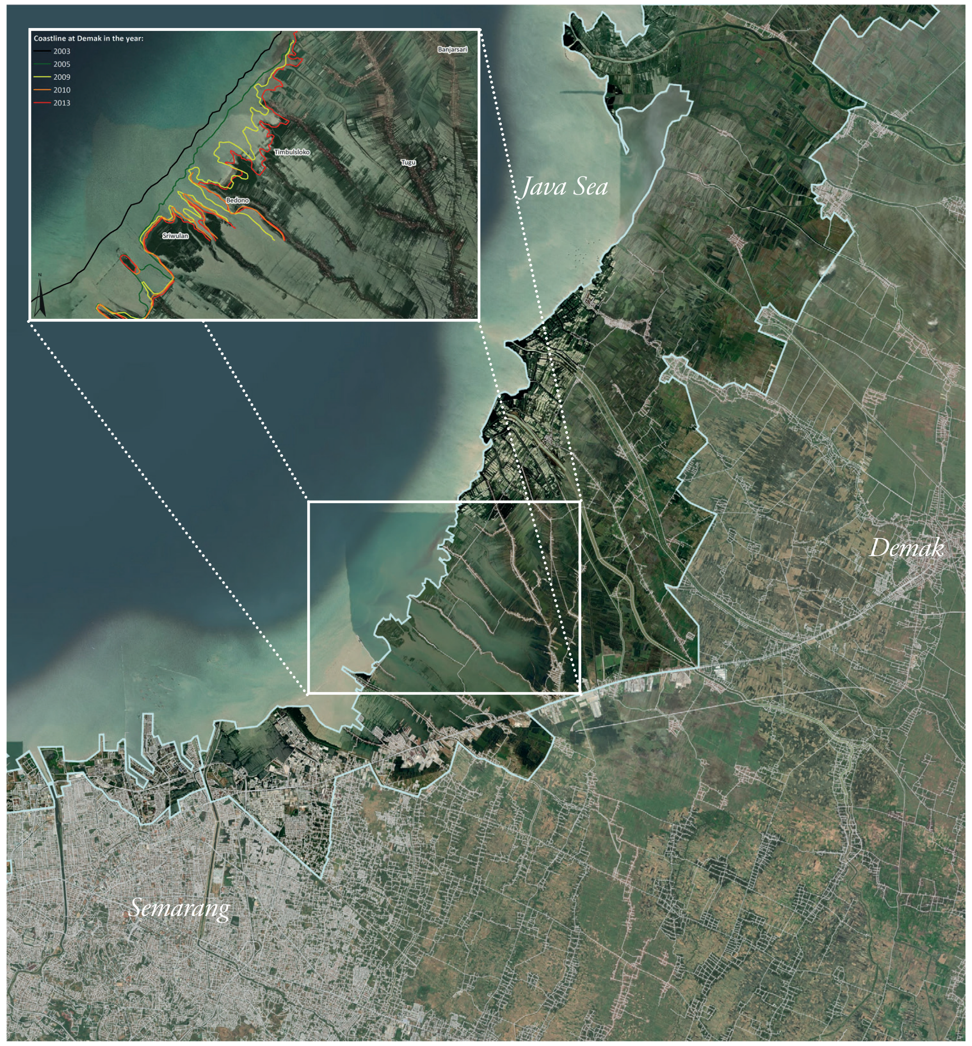
legend

land use (above)
urban
mosaic crops
crops
shrubland
mosaic nature
trees
grassland
sparse vegetation
other

spatial parameters:
urban grid
agriculture land
aquaculture land
river canalization

processes:
coastal erosion
-mangrove destruction

water stress:
-coastal floods



addressed water stress

main: Coastal Floods
cascading:
Soil Erosion
Ground Subsidence

main aim NBS

Reduction of coastal erosion by means of mangrove rehabilitation through constructed permeable water structures that fixate sediment.

scale of implementation

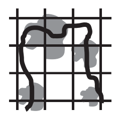
<u>physical intervention</u>
- Permeable structures constructed in front of the coastline, to dampen waves and fixate sediment.
- Natural mangrove restoration
- Repositioning aquiculture ponds

<u>policy guidelines</u>
- Aquiculture governed by community bylaws
- Alignment with government master planning for sustainable development.
- The Biorights incentive mechanism engaging communities in mangrove restoration and aquaculture revitalization.

<u>community practices</u>
- Aquaculture measures and community development plans
- Integrated community-government water management plan
- Coastal Field Schools for new aquaculture management practices and livelihood diversification.
- Reclaimed land managed by communities and owned by the government.
- Community ownership of aquaculture production systems and hardware.

addressed ecosystem

Mangroves, Aquaculture ponds, villages and urban areas



Northern Java Coast

type of cooperation

Local communities implement and maintain permeable water structures.

Local communities are actively engaged in collecting and recording monitoring information.

Regular reports are submitted to the donors (Dutch Sustainable Water Fund, The International Climate Initiative (IKI) of the German Environment Ministry (BMUB) and Waterloo Foundation).

NGO's (Wetlands International and Blue Forests) Manage partnerships, coordinate field-based and outreach activities, empower local communities, facilitate stakeholder dialogue and give ecological expertise.
Knowledge Institutes (Deltares, Wageningen Marine Research and University of Diponegoro) Contribute to design and support monitoring.

Consultancy and Engineering firms manage development guidelines and provide technical advice as well as operational actions (dredging).

type of capital

<u>financial</u>
Maintenance costs will be covered via community managed development funds.

Community and government fund for coastal belt maintenance, up-scaling and sustainable land-use.

Biorights incentive mechanism - Communities receive financial support to develop sustainable livelihoods given active engagement in conservation and restoration measures.

Donors which include the Dutch Sustainable Water Fund, The International Climate Initiative (IKI) of the German Environment Ministry (BMUB) and Waterloo Foundation.

sphere of implementation

The principal objective is to build a stable coastline with reduced erosion by stimulating the rehabilitation of mangroves of the most vulnerable parts of affected coastline in Demak District.
The project is manged by the public private partnership "Building with Nature Indonesia" which follow government master planning for sustainable development. Local stakeholders – including communities – are involved in design, construction and maintenance of measures.
Coastal Field schools ensure capacity building for communities to implement the best sustainable practices.

The Biorights incentive mechanism by the government assures that engaging communities in successful conservation and restoration measures, receive financial support to develop sustainable livelihoods. The reclaimed land is owned by the state, but the sediment dam infrastructure and aquaculture production systems and hardware are of community ownership. The aquaculture measures in the project are governed by community bylaws rooted in community development plans and government master planning.

addressed ecosystem

Mangrove belts play an important role in coastal safety along muddy coasts. They are dynamic systems, with sediment naturally eroding and accumulating as a result of wave and tidal influence. When a mangrove green belt is sufficiently wide and robust, erosion can be compensated, and the coastline restores naturally. They can also protect against wave impact and flooding indirectly by helping to accumulation of sediment which increases shore elevation and slope. Mangroves can also contribute to sediment consolidation and compaction on site. Mangroves are also fertile breeding grounds for fish, and rich sources of timber and non-timber forest products.

type of cooperation

Building with Nature Indonesia is implemented through a public private partnership and in close collaboration with communities in Demak. Each partner brings in specific set of skills, knowledge and experience which play a role in the planning and implementation.

Ecoshape partners directly involved are: Government Agencies (The Indonesian Ministry of Marine Affairs and Fisheries (MMAF) and the Indonesian Ministry of Public Works and Housing (MPWH)) both help create an enabling environment for the Building with Nature programme.

NGO's (Wetlands International and Blue Forest) managing partnerships,coordinates outreach and field-based activities and empowers local communities related to mangrove conservation and restoration.

Knowledge Institutes such as Deltares and Wageningen Marine Research contribute and share knowledge on coastal ecology and geomorphology, and socioeconomics. They are responsible for the design and monitoring of Building with Nature interventions. The University of Diponegoro (UNDIP) in Semarang contributes with local system knowledge for the design and monitoring. Consultancy engineering firms (Witteveen+Bos, Boskalis and Van Oord) support the operation by providing development guidelines and technical advice as well as operational actions (dredging).

Communities are supported with technical expertise and capacitated with sustainable practices of ecosystem monitoring and conservation as well as ecologically sustainable forms of natural extractive occupations and aquaculture.

type of investment

The project is supported mainly with donor funds from the Dutch Sustainable Water Fund, The International Climate Initiative (IKI) of the German Environment Ministry (BMUB) and Waterloo Foundation covering planning and implementation costs, as well as community capacitation and equipment supply costs.

Given active engagement in conservation and restoration measures, communities receive financial support to develop sustainable livelihoods that will generate income. Payments to communities will only be provided subject to successful restoration (Biorights incentive mechanism).

Income from aquaculture and other economic sources provided by mangroves are partially saved in community funds, managed by these same communities, intended to support the management and maintenance of the infrastructures for sediment capture and mangrove ecosystem restoration.

Permeable structures. Retrieved from Bhatt et.al., 2016

Mangrove Restoration. Retrieved from Bhatt et.al., 2016

NBS principles
(extrapolated from Cohen et.al., 2019)

NbS1.- Conservation
Restored mangrove areas are managed locally with sustainable methods to conserve dependant ecosystems and guarantee coastal protection. Reclaimed land is owned by the government, and specific planning laws and legislation ensures guidelines and regulation for its preservation.

NbS2.- Synergies
Given the intrinsic cooperation in the design of the Building with Nature Indonesia programme, synergies are multiscalar and multistakeholder by design. The local communities' benefit from mangrove coastal protection, and in return for maintaining a healthy ecosystem, thrive from increased fishing quality and quantity within mangroves and from ecological enhanced and sustainable aquaculture ponds. Agricultural land also benefits from mangrove protection and sediment fixation, enhancing yields. Subsiding land is mitigated with soil and sediment fixation and wave mitigation, this reduces the need for new groundwater extraction wells, which reduce subsidence.

NbS3.- Site specific context
The 20km coastline extension In the Demak district considered for mangrove restoration is key to mitigate flooding and ecosystem degradation inland for around 70,000 people and estimated to affect 30 million by 2100. The programme decided that this stretch of coastline is essential to restore in order to protect the region from future climate threats.

NbS4.- Transparency & broad participation
Decisions and actions are done with clearly defined goals based on recurrent studies and reports which assess impacts on communities and ecology. The diversity of expertise and fields of stakeholders guarantee that the project is implemented attending the various needs involved. Communities play an active role in the planning and implementation of the chosen methods and projects where tools for cooperation and participation have been introduced, and to be can guarantee the project's success in the long run.

NbS5.- Ecosystem diversity & evolution over time
Building with Nature solutions work with and along the dynamics of nature. For example, by restoring ecosystems so that they once more provide protection against extreme events and offer valuable 'natural capital' (shellfish, timber or recreational opportunities for example). Building with Nature measures will enhance the resilience of the coastal communities and ecosystem in the shorter term and at a smaller scale, thus softening and delaying the impact of hazards.

NbS6.- Landscape scale
Localized interventions with permeable structures for sediment fixation will rehabilitate mangroves and with sufficient replication of these infrastructures, can exponentially restore mangrove belts at the landscape coastal scale. Benefits will be felt inland with land protection and communities also benefiting with increased income and livelihoods.

NbS7.- Trade-offs
Providing that the project is successful in safeguarding coastal communities and their economic activities, the tendency is that this land gains value and pressure from urbanization increases. This can increase groundwater extraction if this activity is not well regulated and monitored which will lead to greater subsidence, compromising aquiculture ponds and the coastal restoration projects. For this reason, it is essential to prioritize awareness of the delicate ecosystem at stake.

NbS8.- Policy integration
The Biorights Incentive mechanism is vital for the project to succeed given that it engages communities in mangrove restoration and aquaculture revitalization by providing support and payments conditioned to their successful participation. Coastal Field Schools are set up in order to capacitate communities on the best practices for sustainable and eco-friendly aquaculture. These initiatives are fully rooted in community development plans and government master planning for sustainable development.

synergies / trade-offs
(provided by the study)

environmental synergies / trade-offs
- Mangrove restoration enhances ecosystems, forest and aquatic species.
- Ecologically restored forests are also likely to be more resilient to change.
- Mixed mangrove aquaculture productivity is optimal, while the surrounding mangroves reduce the spread of disease agents, purify water and maintain their coastal safety and fisheries enhancement functions.

social synergies / trade-offs
- Mangrove based community livelihoods are secured.
- Reclaimed land is managed by communities, requiring engagement with the local ecosystem and sediment capture permeable structures.
- Coastal Field Schools capacitate communities on the best practices for sustainable and eco-friendly aquaculture.

economic synergies / trade-offs
- The Biorights Incentive mechanism engages communities in mangrove restoration and aquaculture revitalization by providing payments conditioned to their successful participation.
- Recovery of pond fisheries production, improvements in income and livelihoods diversification.
- Increased yields of aquaculture, reduce pressure on mangrove and ponds creation.

SDGs
(extrapolated from synergies)

1 No poverty
2 Zero hunger
3 Good health and well-being
4 Quality education
5 Gender equality
6 Clean water and sanitation
7 Affordable and clean energy
8 Decent work and economic growth
9 Industry, innovation and infrastructure
10 Reduced inequalities
11 Sustainable cities and communities
12 Responsible consumption and production
13 Climate action
14 Life below water
15 Life on land
16 Peace, justice and strong institutions
17 Partnerships for the goals

Mapping set

Tana Watershed, Kenya

basemap

legend

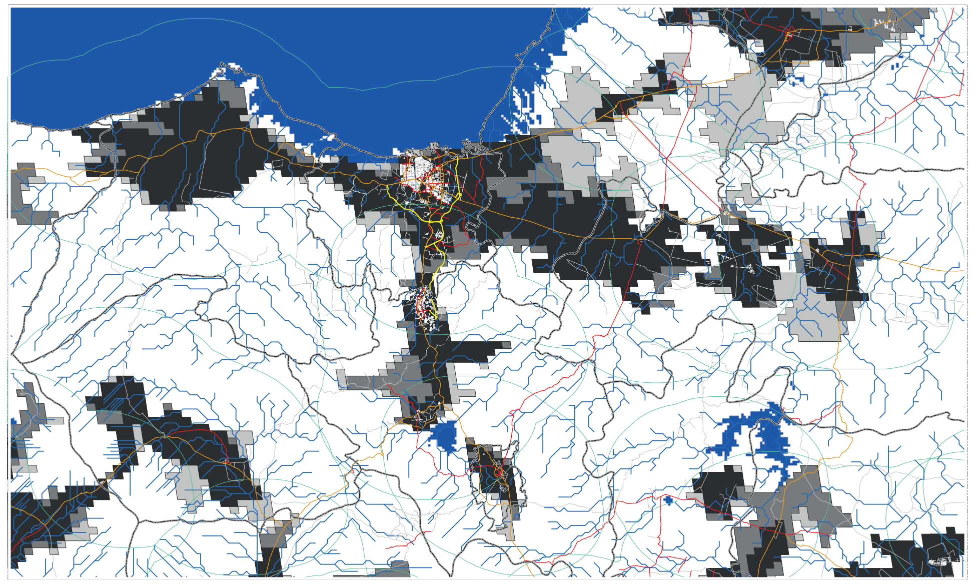
- administrative boundary

roads
- highway
- fast transit road
- regional road
- main road
- local road

water
- water body
- river

urban area
- urban area in 1990
- urban area in 2000
- urban area in 2015
- 10 km around urban area in 1990

0 25 km N



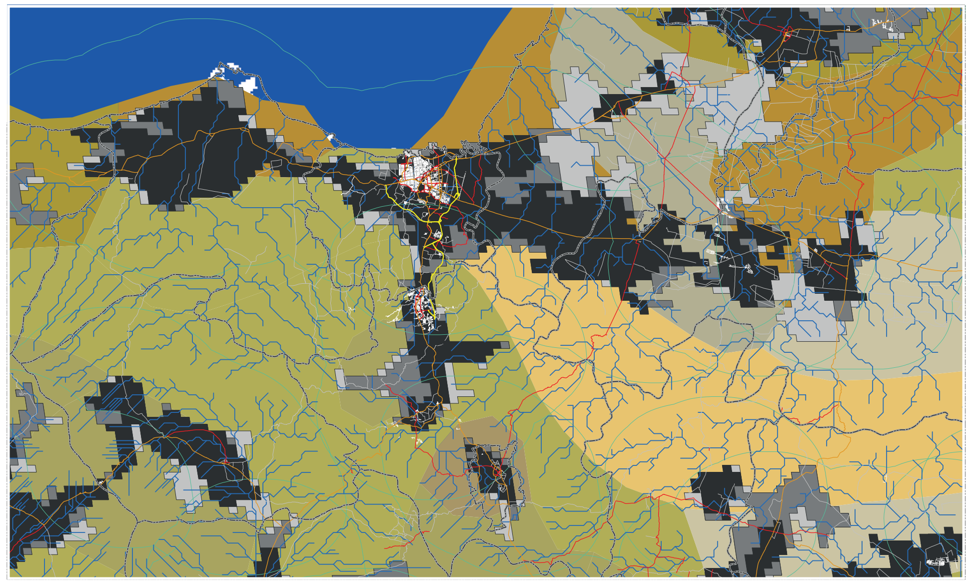
Source: PBL

soil map

legend

- Acrisols
- Cambrisols
- Chernozems
- Podzoluvisols
- Rendzinas
- Ferrasols
- Gleysols
- Phaeozems
- Lithosols
- Fluvisols
- Kastanozems
- Luvisols
- Greyzems
- Nitosols
- Histosols
- Podzols
- Arenosols
- Regosols
- Solonetz
- Andosols
- Rankers
- Vertisols
- Planosols
- Xerosols
- Yermosols
- Solonchaks
- S2-3a
- W2-a

0 25 km N



Source: PBL

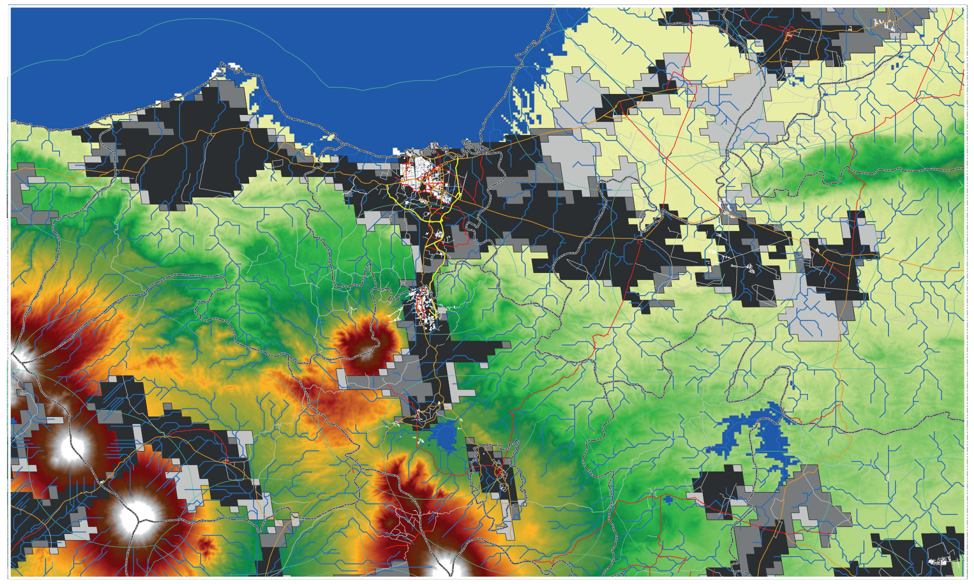
elevation map

legend

height

-428 m +8790 m

0 25 km N



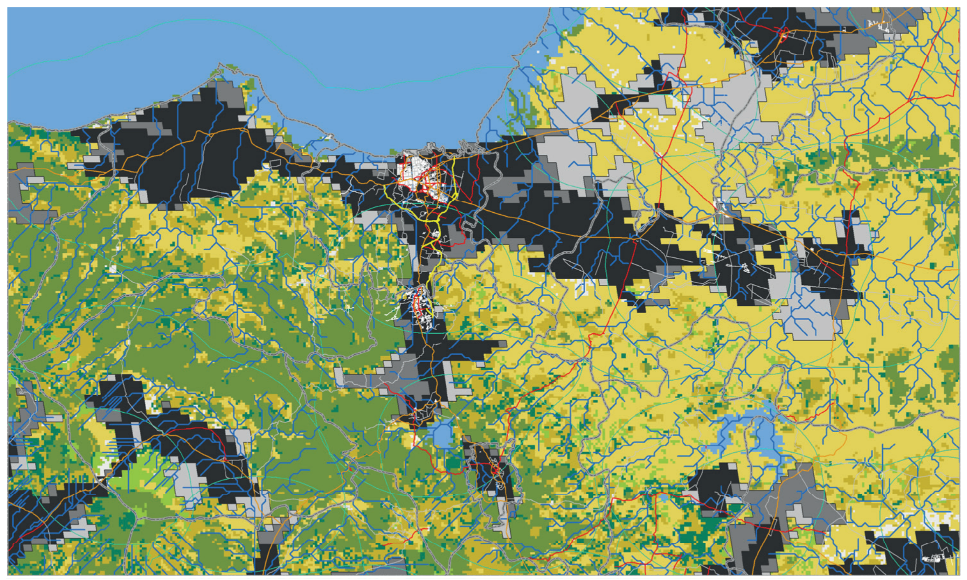
Source: PBL

land-use

legend

- water
- urban area in 1990
- urban area in 2000
- urban area in 2015
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

0 25 km N



Source: PBL

The Building with Nature programme implemented in the case of Demak district shows the potential for NBS success when highly integrated with local communities throughout the process. By focusing on the benefit of local communities, solutions can be appropriated and therefore cared and managed as relevant for community activities. Positive impact for local people (income and welfare) have helped promote the approach and perpetuate long term maintenance as well as efforts to build and incorporate community practices. Securing land rights are imperative for the success of mangrove restoration and land reclamation approaches, which facilitate sustainable master plans to conserve such areas and hold local communities accountable for preservation.

While specific designs for Building with Nature are highly site-specific, depending on local conditions, the general rationale behind the approach as well as the required process behind roll-out of the approach are readily replicable, provided that a favourable environment and sufficient stakeholder capacity are in place.

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4.4.5

Jaguaré Creek Restoration

São Paulo, Brazil

Landscape transformation with built wetlands to restore ecological functions
Source: European Commission (2019)

context reading
the shaping of the risk

spatial context
(custom)

geographical positioning

Tropical climate

TPI= U →

socio/spatial & technical configuration

land use system:
Urban re-naturalization

population growth rate:
high

urban growth:
Planned & Informal

illegal settlements:
medium

level of informality:
high

water technology in place:
Selective water supply and sewage system

main water challenge
(adapted from PBL, 2018 & WWDR, 2018)

too little

drought mitigation

water food and production

too polluted

water purification

erosion control

biological control

water temperature control

too much

riverine flood control

urban stormwater runoff

coastal flood

context reading
instruments to deal with the risk

adaptation typology
(IPCC, 2003)

spatial

Open Spaces
Nature-based retention basins (built wetlands).
Bioswales and rain gardens along the Jaguaré creek.

institutional

Economic Resources
Donations from vicinity private stakeholders
Financial support from the State Fund for Hydric Resources (FEHIDRO)

Equity
Income inequality:
High
Community empowerment:
low
Social cohesion:
medium

Information & Skills
Hydraulic Technological Centre (CTH) part of the São Paulo Polytechnic School developing the hydrological models.
Design by the LabVerde (Landscape Architecture laboratory of the Architecture and Urbanism School).

Institutions
Institutional coordination:
medium
Policy coherence
Transparency

Infrastructure
Protection standards
Operation standards
Technology penetration

NBS
main aim

Re-naturalization of the Jaguare creek restoring ecological functions utilizing a series of multifunctional nature-based solutions applied according to site specificities throughout basin.

implementation
of the NBS

(custom)

sphere of implementation

physical intervention
community practices
policy guidelines

scale of implementation

urban scale
basin scale

addressed ecosystem

point
corridor
patch
network
matrix

type of cooperation

household
community
municipal
intermunicipal
national
international

type of capital

Donations
Government Funds

impact
principles & co-benefits

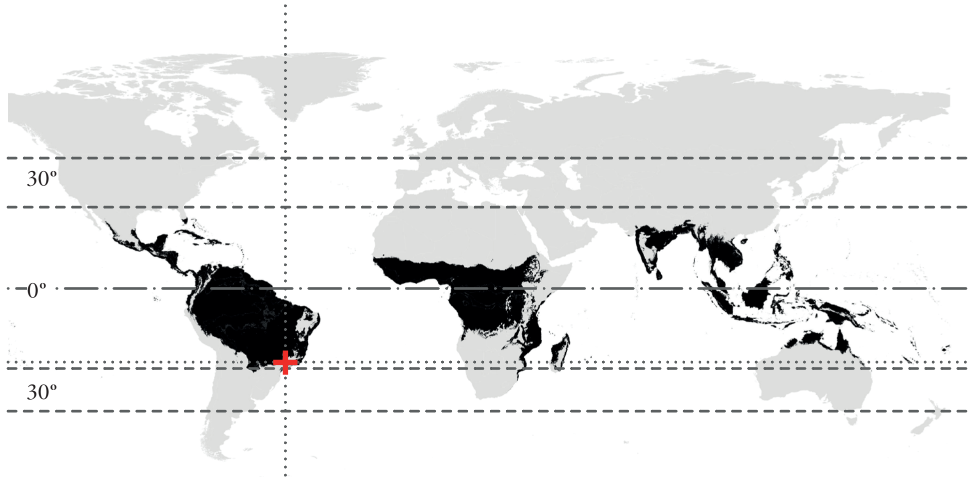
(sources)

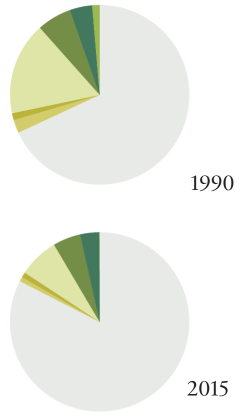
1 No poverty
2 Zero hunger
3 Good health and well-being
4 Quality education
5 Gender equality
6 Clean water and sanitation
7 Affordable and clean energy
8 Decent work and economic growth
9 Industry, innovation and infrastructure
10 Reduced inequalities
11 Sustainable cities and communities
12 Responsible consumption and production
13 Climate action
14 Life below water
15 Life on land
16 Peace, justice and strong institutions
17 Partnerships for the goals

Context reading to water stress
Riverine floods

geographical positioning

P.D = Subtropical
A.P = 1169 mm
T.P.I = U ↘





socio/spatial & technical configuration

land use system:
Creek re-naturalization
Urban land

population growth rate:
xx%
type of urban growth:
planned & unplanned

level of informality:

water technology in place:
Ground water extraction /
Technical water supply & sewage treatment

adaptation typology

built wetlands, bioswales and rain gardens.

National GDP
2.054 trillion USD (2017)

income inequality

community empowerment

social cohesion

information & skills

institutional coordination

keywords

Subtropical climate
Water quality
Water availability
water pollution
storm-water run-off
rainwater floods

the shaping of the water stress

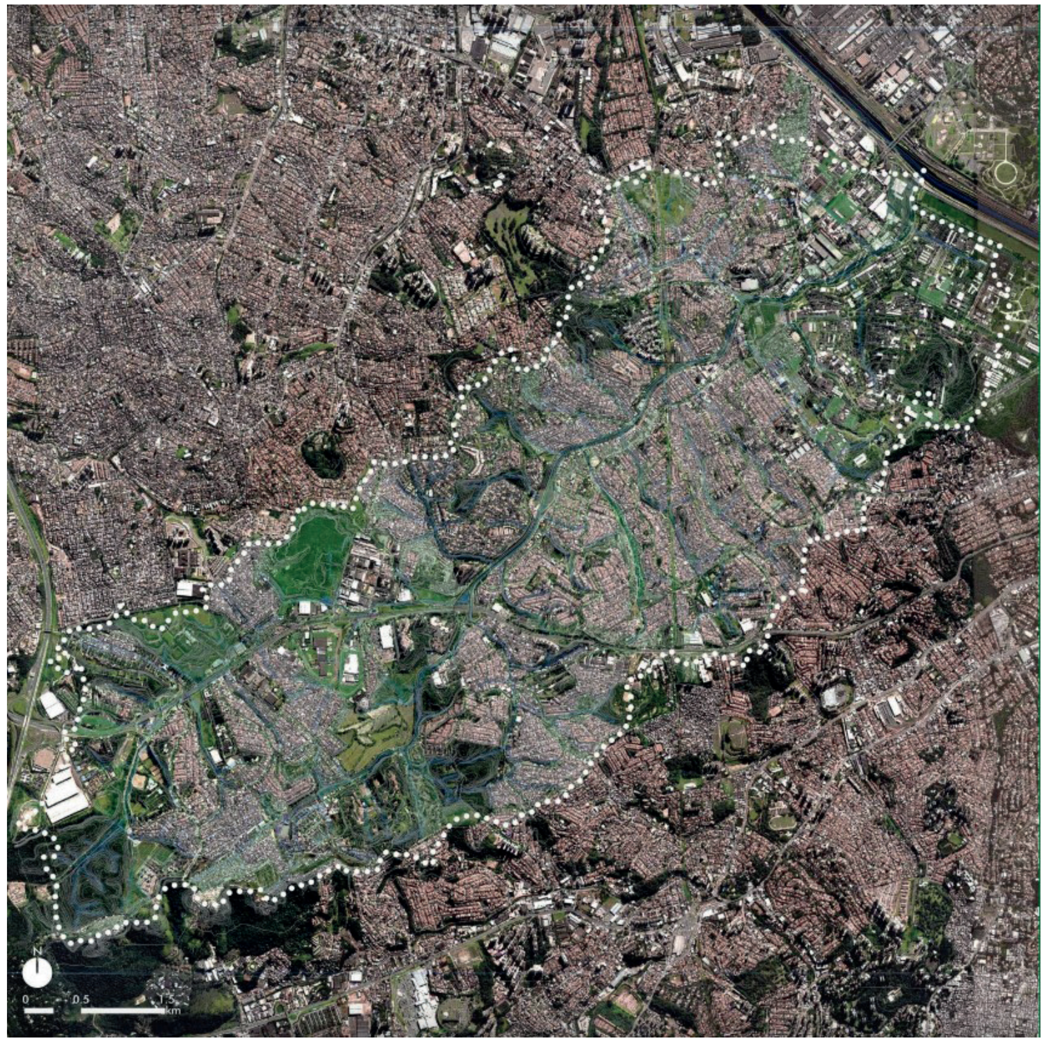
The Jaguaré creek is located in central São Paulo City, and is fully canalised along all of its 25 km. With parts buried underground, and others contained within concrete canals between traffic lanes, the watershed has been deeply modified through this urbanisation process and receives a significant load of domestic and industrial sewage and diffuse pollution. The Jaguaré watershed is a diverse setting with varied landscapes and urban contexts, from its springs to the heavily urbanised area where it then flows into the Pinheiros river. The watershed corresponds to 1/10 of the total 270 km² drainage area of the Pinheiros river, one of the two main watercourses crossing the metropolitan area of São Paulo.

Most of the urban rivers in São Paulo are contaminated with sewage and receive diffuse pollution from the storm-water run-off of impervious surfaces and solid litter. The city is vulnerable to frequent floods, urban heat-island effect and related health problems. The traditional constructed concrete 'piscinões' (built storm-water reservoirs) are not effective in addressing the recurrent floods that occur in the city. The Jaguaré watershed shares most of the challenges with the other water basins of the city. Water quality and storm-water management are intrinsically related to buildings, natural resources, litter and interventions in watercourses.

legend

land use (above)
- urban
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

spatial parameters:
- Jaguaré Watershed Limit
- water streams
- Green areas



addressed water stress

main:
Storm water management
cascading:
Reduce illegal sewage discharge and run-off pollution.
Ecosystem restoration

main aim NBS

Re-naturalization of the Jaguare creek restoring ecological functions utilizing a series of multifunctional nature-based solutions applied according to site specificities throughout basin.

scale of implementation

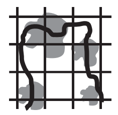
physical intervention
- Interventions such as built wetlands, bioswales and rain gardens are programmed to be implemented along the basin.

policy guidelines
- Implementation design aligned with state and municipal masterplans for Sao Paulo 2024 SABE-SP plan for Universal sewage
- Two plans are designed to be implemented according to different stakeholders and their scale of action on the basin.
- Transferring of families within the contemplated areas within the basin are Aligned with the 2024 Municipal Housing Plan.
- Aligned to the 2040 Urbanization plan of São Paulo which will urbanize informal settlements and propose linear parks.

community practices
- Community participation through local management plans to support implementation of NBS and maintenance.
- Local Schools are engaged as spaces for dissiminating information and discussion on the importance of maintaining healthy local ecosystems.

addressed ecosystem

Degraded lands, informal settlements, large impermeable areas and existing green areas.



Jaguare Creek Watershed

type of cooperation

Local communities cooperate to implement and maintain small scale LIDs

Local municipal and state schools organize events to raise awareness and inform residents on the importance of keeping the local ecosystem healthy and how to reduce flooding and water pollution.

Águas Claras do Rio Pinheiros (Clear Waters of Rio Pinheiros) NGO leads the project, articulating interested parties and key stakeholders which can contribute with the project's implementation.

LabVerde (Landscape Architecture laboratory of the Architecture and Urbanism School) is responsible for the design framework regarding the LIDs to be implemented and correlation with municipal and state master planning.

type of capital

financial
Funds raised by Aguas Claras do Rio Pinheiros NGO from private companies located in the vicinal region which would directly benefit from reduced flooding and pollution.

Financial support from the State Fund for Hydric Resources (FEHIDRO) to enable the project's development.

keywords

physical intervention
policy guidelines
community practices
masterplan allignment

sphere of implementation

This nature-based project was developed to establish new concepts and guidelines to enhance the quality of the Pinheiros river and its tributaries, starting with the Jaguaré creek as a pilot project that developed new technologies in multifunctional high-performance landscapes combining manifold urban issues with integrated long-term monitoring and management.

The project has an innovative approach to addressing point pollution (sewage and industrial discharge) and diffuse pollution (caused by storm-water run-off) with hybrid nature-based and engineered solutions to build urban resilience, support sustainable development and offer quality of life and well-being to urban dwellers. Solutions include built wetlands, bioswales and rain gardens are programmed to be implemented along the basin.

The Jaguaré re-naturalisation project is aligned with municipal and state 2024 masterplan of São Paulo for implementation of universal sewage collection and treatment by the São Paulo State Sewage Company (SABE-SP), known as Clean Creek Program (PMSP) with areas already re-naturalized by this program.

The proposed plan for the Jaguare creek, by Aguas Claras do Rio Pinehrios NGO, modelled by the Hydraulic Technological Centre (CTH) part of the São Paulo Polytechnic School and designed by LabVerde (Landscape Architecture laboratory of the Architecture and Urbanism School) works with two water management plans. The first, contemplates the enhancement of the collection, transport and treatment of residual water, linked to the suppression of clandestine sewage connections in the drainage system. This plan is under the supervision of the municipality, which oversees social housing plans and slum re-urbanization. The second plan focuses on the removal of pollutant diffused water from rain run-off, and which constitutes the focus of the project. By addressing these issues simultaneously with both plans, re-naturalization can occur rapidly.

Through direct action of Aguas Claras do Rio Pinheiros NGO, community participation through local management plans to support implementation of NBS and maintenance was stimulated, as well as activities for water quality conservation conscientization informing local groups and businesses of the importance to well manage water runoff using nature-based solutions as well as reduction of direct and indirect water pollutants. Local schools were also engaged as spaces for disseminating information and discussion on the importance of maintaining healthy local ecosystems.

(Patch)

(matrix)

addressed ecosystem

The city of São Paulo is the largest megacity in South America and has been developing with a heavily car-oriented approach and supported by hard engineered solutions for urban infrastructure systems. Set in a humid semitropical region, strong rainfall and monsoon-like storms are common, which commonly compromise the cities engineered drainage systems as well as overflow its rivers. The Jaguaré re-naturalisation project embraces the watershed with an integrated and systemic approach. It aims to restore the ecological processes and functions of the remaining areas that are in the river floodplain and to relocate some occupations in flood-prone areas to create multifunctional wetlands to store, treat and infiltrate storm water, with multiple benefits to the city.

keywords

NGOs
Academic Institutions
State Funds
community
municipal

type of cooperation

Considering that institutional and social mobilization is essential for the success of urbanization and water policy, the studies conducted for the basin present advantages for public and private stakeholders throughout the basin. The NGO Águas Claras do Rio Pinheiros (Clear Waters of Rio Pinheiros), was responsible for engaging stakeholders from public to private, facilitating cooperation for the shared benefit in the Jaguaré Basin.

Aguas Claras hired the University of São Paulo's Foundation Hydraulic Technological Centre (FCTH) part of the Polytechnic School of São Paulo for developing the hydrological models to accommodate storm water and give the framework to the design by LabVerde (Landscape Architecture laboratory of the Architecture and Urbanism School).

The project also dialogues with other institutional actors, be it because of their policy planning capacity, their central role in implementation action or for their data base support. From these, key partners include the Department of of Water and Energy (Departamento de Águas e Energia Elétrica – DAEE), State of São Paulo Environmental Company (Companhia Ambiental do Estado de São Paulo – CETESB), Metropolitan Company of Water and Energy (Empresa Metropolitana de Águas e Energia S. A. EMAE), as well as the Municipality of São Paulo through its agencies such as the sub city hall of Butantã, Municipal Secretaries of Housing, Urban Development, Urban Infrastructure and Greenery and Environment.

The Jaguaré re-naturalisation project is aligned with municipal and state 2024 masterplan of São Paulo for implementation of universal sewage collection and treatment by the São Paulo State Sewage Company (SABE-SP), known as Clean Creek Program (PMSP) with areas already re-naturalized by this program.

NBS

Re-naturalization of the Jaguare creek restoring ecological functions utilizing a series of multifunctional nature-based solutions applied according to site specificities throughout the basin.

keywords

private
public
State fund

type of investment

The Jagauré Creek Project received most of its financial resources from the State Water Resources Fundo of São Paulo (FEHIDRO). Funding from implementation was organized through donations from interested private and public stakeholders within the basin. Where existing water management and greening projects were planned or implemented in sites within the basin, these were funded independently according to the groups which owned the land in question, keeping in mind the Jagauré Creek masterplan. This is the case of the University of São Paulo which has its West Campus within the Jaguaré basin and has its own water and environment funded projects such as the Sustainable Campus program.

The restructuring of creeks would transform them in leisure spaces like parks.
FCTH/Revista Labverde (2017).

NBS principles

NBS Principles

NbS1.- Conservation
NbS2.- Synergies
NbS3.- Site specific context
NbS4.- Transparency & broad participation
NbS5.- Ecosystem diversity & evolution over time
NbS6.- Landscape scale
NbS7.- Trade-offs
NbS8.- Policy integration

NbS1.- Conservation
Re-naturalization and maintenance are done by public agencies with community support mediated by NGO Águas Claras.

NbS2.- Synergies
Project planning, execution and maintenance is done with public and academic institutions in alignment with water and sewage projects as well as housing plans for population relocation. Specific sites have private projects which are aligned to the Jaguaré basin project.

NbS3.- Site specific context
The methodology developed for identifying the potentiality of water management sites named or Hydro-landscape Zoning (Zoneamento Hidropaisagistico) considers the specific characteristics of water retention and absorption within the basin, in order to more accurately propose solutions to cope with water quantity and quality.

NbS4.- Transparency & broad participation
Coordinated by the Águas Claras NGO, engaging with local community stakeholders to better understand context related issues and potential for community management. Academic partners in the region are engaged to study and develop hydrological models to access potential areas for water management as well as design application of nature-based solutions. Public agencies support project implementation and phasing as well as funding. Municipal and State agencies act in cooperation to manage water and areas contemplated for interventions in the project.

NbS5.- Ecosystem diversity & evolution over time
Regeneration and re-naturalization of the creek will enhance overall ecosystem of parks in the area as well as reduce pollution in the larger Pinheiros River basin which cuts through the city of São Paulo.

NbS6.- Landscape scale
Intervention contemplates the totality of the basin for maximum impact potential with specific sites considered by the "hydro-landscape zoning" method, proposing specific nature-based solutions according to the site limitations.

NbS7.- Trade-offs
It is not clear if the project contemplates the economic disparity and inequality between high and low social classes residing in the area and given the projects public space betterment as an asset for leisure, this can cause green gentrification of lower social classes residing in the area.

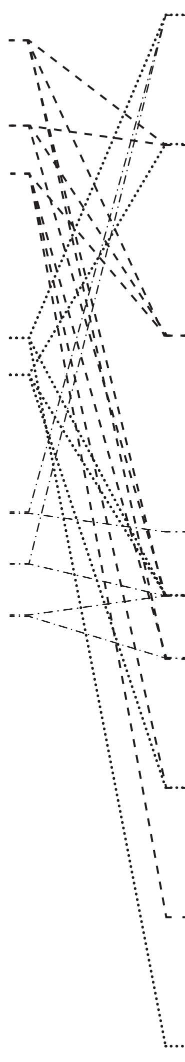
NbS8.- Policy integration
Alignment with the SABE-SP water and sewage universal coverage and service plan of 2024. Areas contemplated for and relocation of families according to the Municipal Housing Plan of 2024 and the 2040 São Paulo City Urbanization Plan.

synergies / trade-offs

environmental synergies / trade-offs
- Ecosystem enhancement and health restoration can reduce water related diseases and outbreaks of infections from insects (e.g., Zika virus transmission by mosquitoes).
- With the reduction of floods, there will also be a reduction of diseases from contact will polluted water.
- Pinheiros River, one of the two main rivers which cut through Sao Paulo, will no longer receive as much polluted water as well as alleviate anti flood mechanisms downstream.

social synergies / trade-offs
- Potential for regulation and formalization of buildings in the area.
- Increase of green and blue areas in densely packed grey urban areas allowing for better urban microclimate and natural leisure spaces.

economic synergies / trade-offs
- Increased land value of the area, stimulating more economic potential and businesses to thrive in the area.
- Green gentrification can affect families and businesses not contemplated within the project area.
- Reduction in maintenance costs and disaster financial aid given the reduced flood impact.



SDGs

1 No poverty
2 Zero hunger
3 Good health and well-being
4 Quality education
5 Gender equality
6 Clean water and sanitation
7 Affordable and clean energy
8 Decent work and economic growth
9 Industry, innovation and infrastructure
10 Reduced inequalities
11 Sustainable cities and communities
12 Responsible consumption and production
13 Climate action
14 Life below water
15 Life on land
16 Peace, justice and strong institutions
17 Partnerships for the goals

Mapping set
Tana Watershed, Kenya

basemap

legend

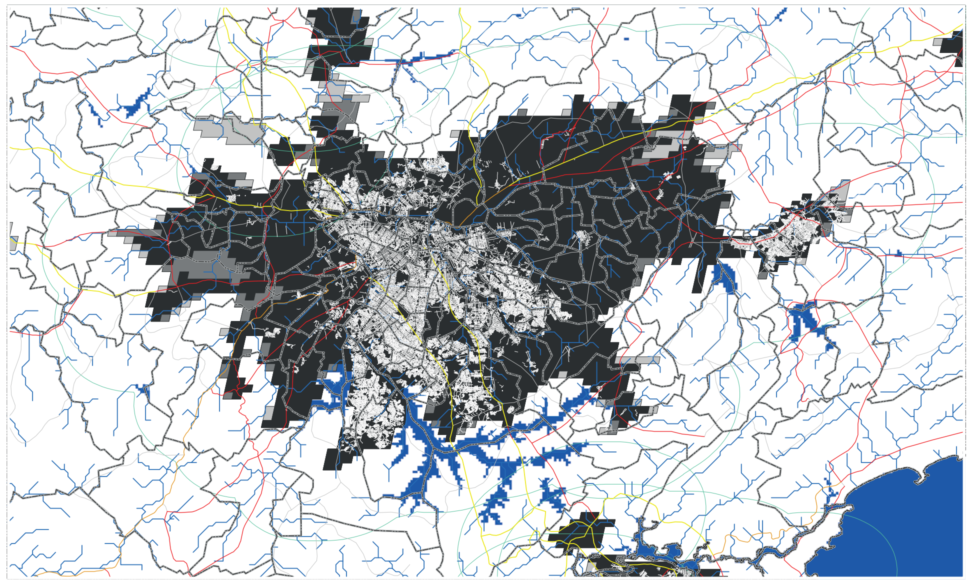
- administrative boundary

roads
- highway
- fast transit road
- regional road
- main road
- local road

water
- water body
- river

urban area
- urban area in 1990
- urban area in 2000
- urban area in 2015
- 10 km around urban area in 1990

0 25 km N



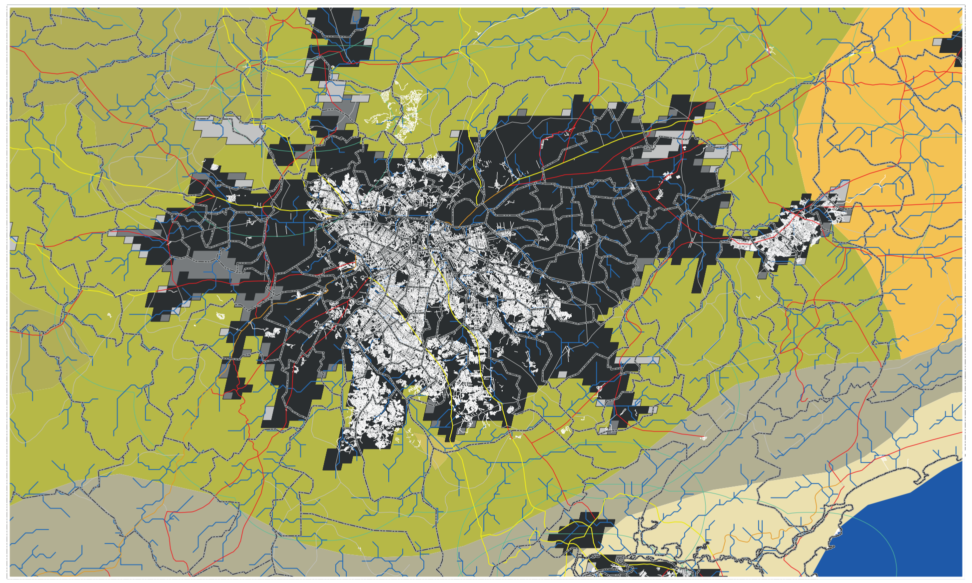
Source: PBL

soil map

legend

- Acrisols
- Cambrisols
- Chernozems
- Podzoluvisols
- Rendzinas
- Ferrasols
- Gleysols
- Phaeozems
- Lithosols
- Fluvisols
- Kastanozems
- Luvisols
- Greyzems
- Nitosols
- Histosols
- Podzols
- Arenosols
- Regosols
- Solonetz
- Andosols
- Rankers
- Vertisols
- Planosols
- Xerosols
- Yermosols
- Solonchaks
- S2-3a
- W2-a

0 25 km N



Source: PBL

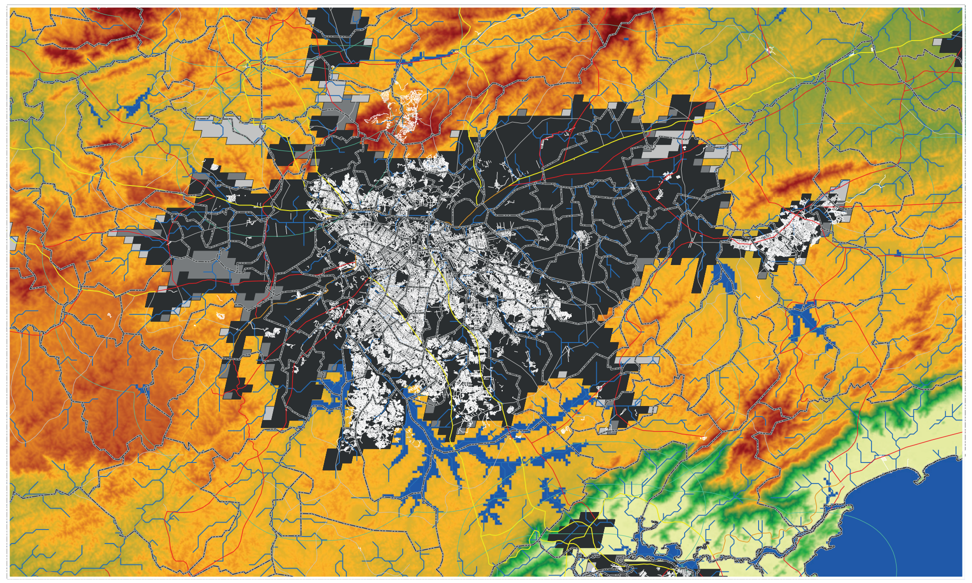
elevation map

legend

height

-428 m +8790 m

0 25 km N



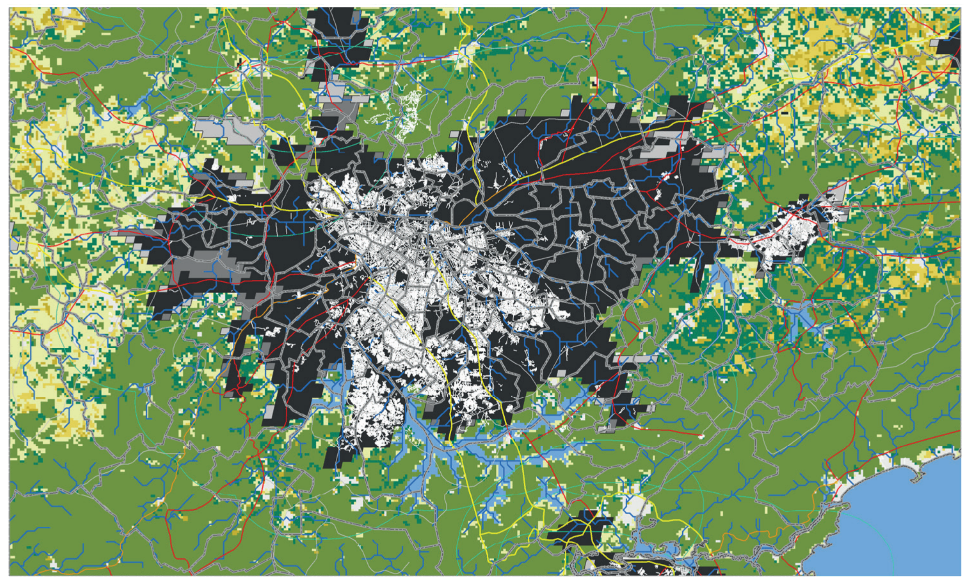
Source: PBL

land-use

legend

- water
- urban area in 1990
- urban area in 2000
- urban area in 2015
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

0 25 km N



Source: PBL

The Jaguaré Creek Project is a pilot project of the Aguas Claras do Rio Pinheiros initiative. This project applies a methodology of landscape reading based on water potential which can be replicated throughout the creek basins which feed the Pinheiros and Tietê rivers (main rivers of São Paulo). The initiative has also innovated by diversifying its funding contribution, seeking local stakeholders with an interest on enhancing water management capacity in the area to aid with funds disobliging dependency sole on state funding.

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4.4.6
Flood risk management
Sponge city concept

Ningbo, China

Landscape transformation with built wetlands to restore ecological functions
Source: Tang et al. (2018)

context reading — the shaping of the risk

spatial context
(custom)

<u>geographical positioning</u>

Subtropical climate

TPI= D →

<u>socio/spatial & technical configuration</u>

land use system:
Peri-urban agricultures

population growth rate:
high

urban growth:
Planned & Informal

level of informality:
low

water technology in place:
"Water town"
Outdated grey system

main water challenge
(adapted from PBL, 2018 & WWDR, 2018)

<u>too little</u>

drought mitigation

water food and production

<u>too polluted</u>

water purification

erosion control

biological control

water temperature control

<u>too much</u>

riverine flood control

urban stormwater runoff

coastal flood

context reading — instruments to deal with the risk

adaptation typology
(IPCC, 2003)

<u>spatial</u>

Open Spaces (Urban parks)
Water canals
Peri-urban agricultures

<u>institutional</u>

Economic Resources
Government

Equity
Income inequality:
High
Community empowerment:
low
Social cohesion:
N/A

Information & Skills
high

Institutions
Institutional coordination:
high
Policy coherence & transparency
high

Infrastructure
Protection standards
in revision

Technology penetration
high

NBS — main aim

Hybrid approch, combining green-blue infrastructure (agricultural plains, water canals and wetlands) with the upgrade of grey infrastructure (tanks and tunnels).

implementation — of the NBS

(custom)

<u>sphere of implementation</u>

physical intervention

policy guidelines

<u>scale of implementation</u>

urban scale

basin scale

<u>addressed ecosystem</u>

point

corridor

patch

network

matrix

<u>type of cooperation</u>

household

community

municipal

intermunicipal

national

international

<u>type of capital</u>

knowledge

Government Funds

impact — principles & co-benefits

(sources)

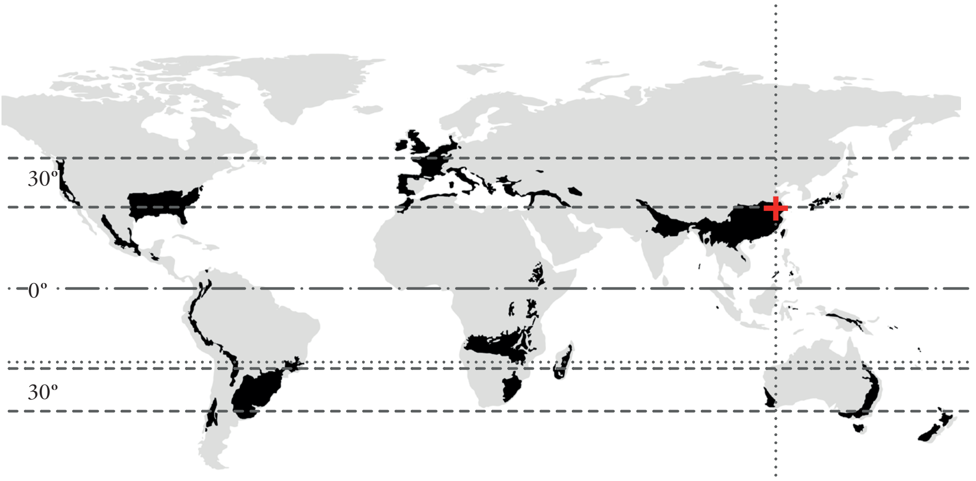
1. No poverty
2. Zero hunger
3. Good health and well-being
4. Quality education
5. Gender equality
6. Clean water and sanitation
7. Affordable and clean energy
8. Decent work and economic growth
9. Industry, innovation and infrastructure
10. Reduced inequalities
11. Sustainable cities and communities
12. Responsible consumption and production
13. Climate action
14. Life below water
15. Life on land
16. Peace, justice and strong institutions
17. Partnerships for the goals

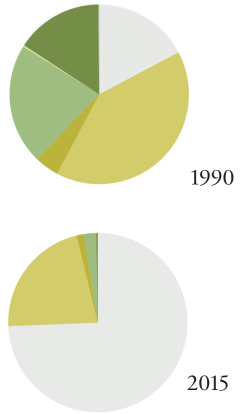
Context reading to water stress

Coastal Flood Plain problems
Pluvial flooding
Coastal flooding
Water logging

geographical positioning

Subtropical climate
P.D = Monsoon
A.P = 1400 mm
T.P.I = U→





socio/spatial & technical configuration

land use system:
(left)

population growth:
fast growing city

type of urban growth:
planned & unplanned

level of informality:

water technology in place:
"Water town"
Outdated grey system

adaptation typology

built wetlands, bioswales and rain gardens.

National GDP
2.054 trillion USD (2017)

income inequality

community empowerment

social cohesion
N/A
information & skills

institutional coordination

keywords

Pluvial floods
Fluvial floods
Estuarine/marine floods
Water logging
'Water towns'

The water-related challenge

The area of Ningbo consists of two ports with an urban center that is located 20 km inland from the Hangzhou estuary. The most recent urbanization takes place in the big coastal plain, there where the Fenghua and Yao Rivers come together and from where the Yong River leads to the sea.

The plain area receives around 1,400 mm rain annual, in an intense pattern of rainstorms. The area also suffers from cyclonic depressions in early summer and monsoons and typhoons in late-summer and early-autumn. These leads to pluvial flooding: surface water and groundwater overflow (Tang et al, 2018). Next pluvial the city also suffers from fluvial floods that rush down to the coastal plain from mountainous catchments inland. The water threats are complete here with the additional estuarine and marine flooding due to extreme high-water elevations that occur when spring tides coincide with typhoon driven storm surges (Tang et al, 2015).

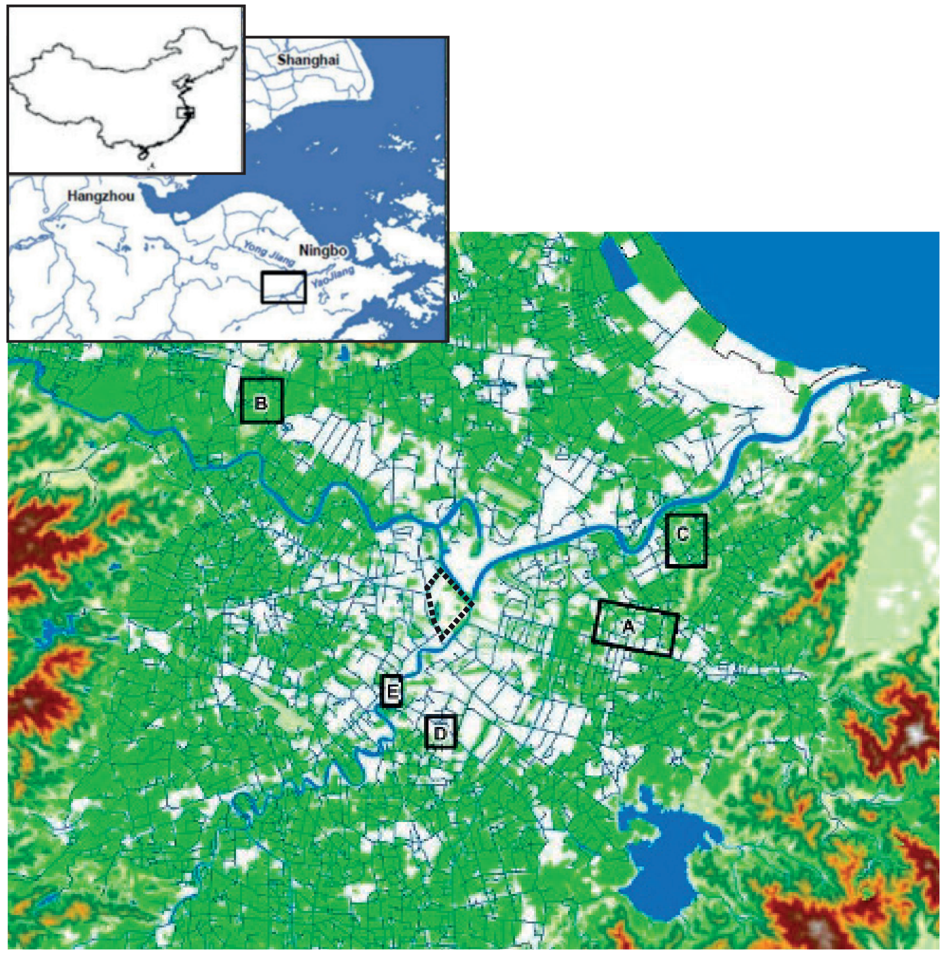
The rivers, waterways and irrigation canals are forming the basic conditions for the rural and urban settlements and thus also organizing the economic system. The so called 'water towns' have a very distinct lay out and architecture wherein residential areas are inside the city walls. The houses have their front door facing the land while the back door was connected to the waterway to transport and deliver goods and products (Zhou, 2014 in Tang, 2018).

These small 'water towns' around Ningbo are expanding into the coastal plains and when this continues the next few decades the coast will be urbanized. With the urbanization also the demand for qualitive freshwater resources for agriculture, industry and households will increase. Not only these basic conditions are vulnerable but also the position the coastal plain will make the areas vulnerable for flooding, caused by climate change, increased rainfall intensity and sea-level rise. Moreover, the urbanization progresses the flood risks even more. Sealed soils, like petrified soils and urban developments are replacing open soils like farmland, marshland, parkland and lakes, that had a high abortion capacity. Based on current population and economic growth trends by 2070, Ningbo will be ranked 14th out of 136 port cities with high exposure to climate extremes (Hanson et al., 2011).

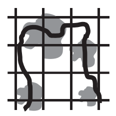
legend

land use (above)
- urban
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

spatial parameters (right)
- old gated city boundary
- location of sponge city projects
- network canals & natural water bodies
- agricultural plain



Location of Ningbo and its Sponge City projects. Source: Griffiths, 2020.

addressed water stress	*main aim NBS*	*scale of implementation*	*addressed ecosystem*	*type of cooperation*	*type of capital*
sewage discharge; flooding; surface water; water conservation, freshwater supply.	Hybrid approch, combining green-blue infrastructure (agricultural plains, water canals and wetlands) with the upgrade of grey infrastructure (tanks and tunnels).	<u>physical intervention</u> - Hybrid systems: Blue Green Infrastructure (BGI), Sustainable drainage systems (SUDS), upgrade of tanks and tunnels <u>policy guidelines</u> - “Five water management” - Improve protection standards	 Watershed System of watercanals, constructed wetlands, agricultural plain	Planning: Chinese Central Government Investment: National Development and Reform Commission (NDRC) Planning and design: Ministry of Finances (MOF) Ministry of Housing and Urban-Rural Development Munistry of Water Resources (MWR) Construction and maintenance: Local Governemnt	<u>social</u> none Continuous knowledge-based development as core element for the Sponge City Project <u>financial</u> Chinese government and Chinese banks

keywords

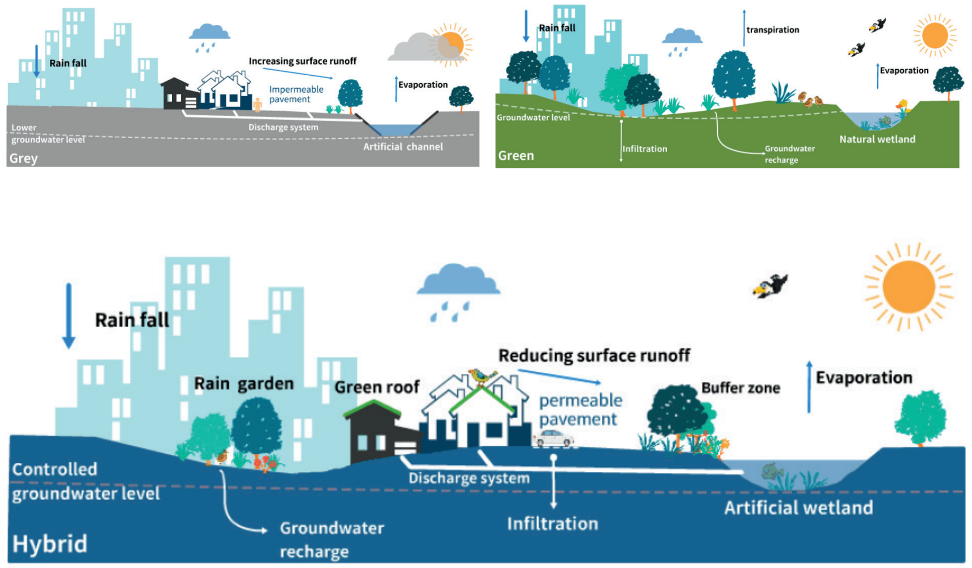
Blue Green Infrastructure (BGI)
Sustainable drainge systems (SuD)
Upgrade tanks and tunnels
Improve protection standards

sphere of implementation

The municipality of Ningbo introduced the "Five Water Management" policy after the severe floods of 2013. This policy targets at managing sewage discharge, prevent flooding, improve quality of surface water, water conservation and fresh water supply. Especially the combination of grey - with green infrastructure, called the hybrid approach, is used to reach the objectives in these urbanizing coastal plains (Qi et al, 2020).

Three years later, in 2016, some of these urbanizing areas in the Ningbo plains became part of the Central Government's "Sponge City" program. The program covers new sustainable water planning strategy in 30 Chinese cities. However, the core concept is not entirely new it originates from traditional Chinese "Water Town" practices. This was already developed by Ningbo in 2013 (Qi et al, 2020).

The Sponge City Program has three main interests: utilizing existing Blue Green infrastructures, upgrade traditional engineered drainage systems and multi functionality. The focus on using (existing) Blue Green Infrastructures is to improve the effective control of urban peak runoff and storing and filtering stormwater. The upgrade of traditional engineered drainage systems (like tanks and tunnels) is to improve current land-drainage protection standards to balance peak discharges and to alleviate stormwater. The last interest is multi-functionality in drainage design in order to maximize ecosystem services (Chan et al, 2018).



keywords

peri-urban and urban waterways
constructed wetlands
agricultural plains
watershed restoration

Scale of the implementation & addressed ecosystem

The implementation of the Sponge City Program is done in the urbanizing agricultural area by the (re) construction of waterways and purification zones. The blue-green structures are retrofitted in the urban tissue of the existing and also in the new layouts of new town developments, in combination with agricultural uses in the peri urban areas.

In these areas the reintroduction of rice or lotus as agricultural crops would be inappropriate. These species have a little capacity to remove pollutants from contaminated urban runoff and cannot be harvested as safely edible agriculture produce. Although rice and lotus have been used a lot for their peculiar flood-resistant life cycles and economic values, they thus cannot solve Ningbo's water quality issues. More effective are floral species such as Water Pennywort (Hydrocotyle ranunculoides), Reeds (Phragmites, Sparganium and Typha), and Bamboo (Bambuseae) in removing key pollutants like total nitrogen or phosphate (Zhou, 2011, in Tang, 2018).

keywords

"command and control"
inexistent community engagement
"River Chief" mechanism

type of cooperation

The support for the Sponge City Program is by a strong political will, coupled with a "command and The support for the Sponge City Program is by a strong political will, coupled with a "command and control" style of environmental management (Tang et al, 2018). The Sponge City concept itself does not involve active stakeholder engagement or stakeholder participation, particularly with respect to residents (Qi et al, 2020). The research of Faith Ka Shun Chan (2020) concluded that the general Ningbo public is not very aware and not engaged with Sponge City Program and urban water management practices. However, when communities live nearby the Sponge City Program sites they do recognize their value and will give their support to future Sponge City Program projects.

To support the implementation of the Sponge City concept there is a "Code for the design of urban green space" which has been improved and officially published. In particular, this document emphasizes the design and construction of urban green-space to improve drainage discharge; the utility of space for stormwater storage; the relationship between soil type, infiltration, and discharge volumes; and minimum allowable discharge rates during the normal and wet conditions to maintain required soil field capacities. Next to that the "Code for design of urban road engineering" is also revised to accommodate the requirements of Sponge City practice (Chan et al, 2018)

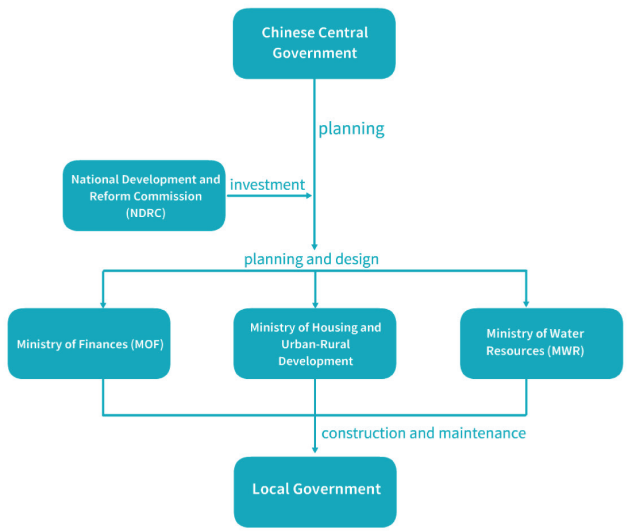
The most important governance aspect of the Sponge City Project is continuous knowledge-based development. This was established by improving the multi-sector management collaboration. In 2018 China's Ministry of Water Resources introduced a new measure: the River Chief mechanism in which the responsibility for protecting bodies of water is put on the shoulders of government officials. It uses the well-known cultural hierarchy to improve coordination between various government organs. This addresses the question of inter-jurisdictional cooperation which is a problem in China (Chan et al, 2020). Another weak point is the participation and cooperation of communities, companies or other stakeholders. In order to achieve the maximum benefits for society, environment, and economy the Sponge City Project needs to utilize interdisciplinary knowledge in the future, working together with local communities and NGOs (Qi et al, 2020).

keywords

one-sided knowledge gathering
central : city : district financing

type of capital

The capital utilized in this case is monetary capital which is coming from the Chinese government and Chinese banks. The larger area developments were carried out in Public Private Partnership constructions, where construction firms are working together with local government. Ningbo was also appointed as a pilot city for the World Bank Climate Resilient Cities (CRC) program (Griffiths et al, 2019). The funding ratio used for developments in Ningbo was 2: 1: 1 (central government: city : district financing). This includes approximately US$ 0.17 billion from central finance, and US$ 0.08 billion from city and district governments. An additional US$ 0.6 billion has been sourced from PPP or engineering, procurement and construction (EPC) contracts, though notably only one PPP project had been approved by July 2018 (Griffiths et al, 2019).



Institution	Roles/Duties
Ministry of Housing and Urban and Rural Development (HMURD)	Operates and delivers SCP practices and is responsible for all SCP construction projects in the allocated 30 pilot Chinese cities.
Ministry of Water Resources (MWR)	Responsible for the land drainage system, offloading stormwater, and urban surface water management including all pluvial or inland floods.
Ministry of Finance	Responsible for financing and dealing with funds to support the SCP development.
Local Planning Department	Collaborate with HMURD and MWR to integrate SCP practice into local development plans for planning processes.
Land Resources Bureau	Coordinate land-use management-related work with the SCP projects and practices.
Environmental Protection Bureau	Responsible for urban freshwater quality and environmental monitoring.
Ministry of Forestry	Manage vegetation, green spaces, and maintenance of flora in the SCP practice.
Non-Governmental Organizations (NGOs) and Community groups	Present the public views and opinions of residents living by the SCP infrastructure (SCP Parks) to the Governmental bureaus and enhance participation.
Developers	To develop the surrounding areas that affiliate with the SCP infrastructure and engage with the municipal governments to enhance Public–Private–Partnerships (PPPs).
Banks and Insurers	To provide financial support and insurance for the SCP projects.

NBS impact

Principles, synergies & SDGs

NBS principles

NBS Principles

NbS1.- Conservation
NbS2.- Synergies
NbS3.- Site specific context
NbS4.- Transparency & broad participation
NbS5.- Ecosystem diversity & evolution over time
NbS6.- Landscape scale
NbS7.- Trade-offs
NbS8.- Policy integration

<u>NbS1.- Conservation</u>
The Sponge City Program in Ningbo is not primarily aiming at nature or biodiversity conservation. It is aiming at recovering or simulating natural hydrological conditions via the re-use of agricultural watersystems.

<u>NbS2.- Synergies</u>
The water quality in urban catchments and rivers has been improved. Nutrient levels have declined and waterlogging has been alleviated, improving the urban living environment and also life in the water. In the urban context, agriculturural land is actually replaced by parks and urban area.

<u>NbS3.- Site specific context</u>
The core concept originates from ancient Chinese "Water Town" practices, where farmers traditionally used farmland as flood buffer zones for urban areas. Because of the density and speed of the urbanization NBS needs to be combined with grey infrastructure, resulting in a 'hybrid approach'.

<u>NbS4.- Transparency & broad participation</u>
The implementation of the "Sponge City" policy is top-down organized by different government sectors. Local communities were not involved in decision-making, construction and maintenance. However communities that live nearby the SCP sites do recognize their value and support future SPC projects.

<u>NbS5.- Ecosystem diversity & evolution over time</u>
The Sponge City Program is top down organized and involves creation of urban greens. It might involve local communities in the future.

<u>NbS6.- Landscape scale</u>
The Sponge City Program is carried out at certain urbanization sites and solves water issues at floodplain level.

<u>NbS7.- Trade-offs</u>
The local livelihood of existing farmers and the preservation or creation of natural areas seems to be absent in the program. It is solely designed to contribute to a green, clean and save urban living environment.

<u>NbS8.- Policy integration</u>
This top down organized water program involves multi-level government cooperation and coordination between urban planning, agricultural and water sectors. In 2018 the River chief mechanism was introduced to solve inter-jurisdictional cooperation. It uses party hierarchy to improve coordination between various government organs.

synergies / trade-offs

environmental synergies / trade-offs
- Clean water (pollutants, nutrients)
- Introduction of wetland ecosystems

social synergies / trade-offs
- Reduction of floodings
- Quality of the living environment (urban green, heat island)

economic synergies / trade-offs
- Extra jobs for maintaining green systems
- Long-term savings in flood damage

SDGs

1 No poverty
2 Zero hunger
3 Good health and well-being
4 Quality education
5 Gender equality
6 Clean water and sanitation
7 Affordable and clean energy
8 Decent work and economic growth
9 Industry, innovation and infrastructure
10 Reduced inequalities
11 Sustainable cities and communities
12 Responsible consumption and production
13 Climate action
14 Life below water
15 Life on land
16 Peace, justice and strong institutions
17 Partnerships for the goals

Mapping set
Tana Watershed, Kenya

basemap

legend

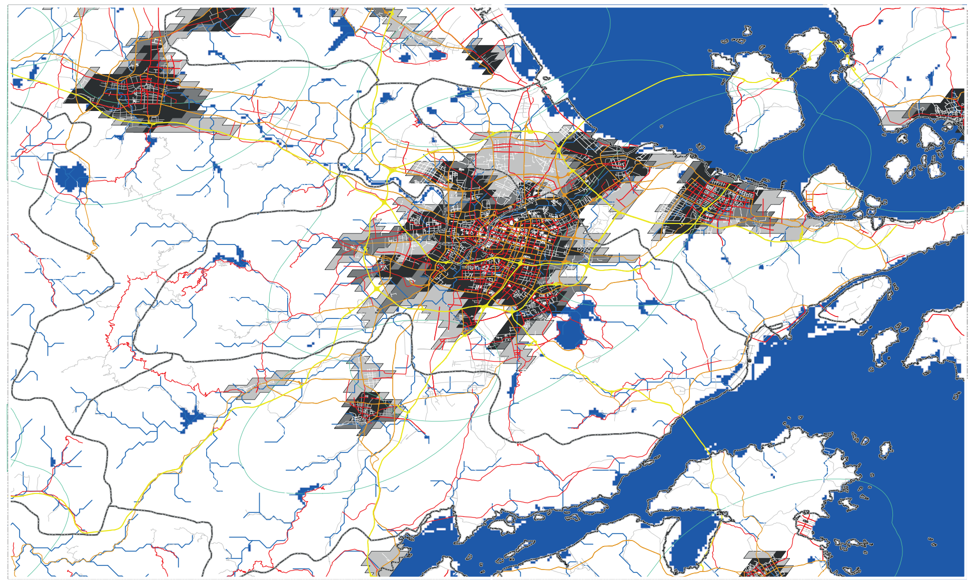
- administrative boundary

roads
- highway
- fast transit road
- regional road
- main road
- local road

water
- water body
- river

urban area
- urban area in 1990
- urban area in 2000
- urban area in 2015
- 10 km around urban area in 1990

0 25 km N



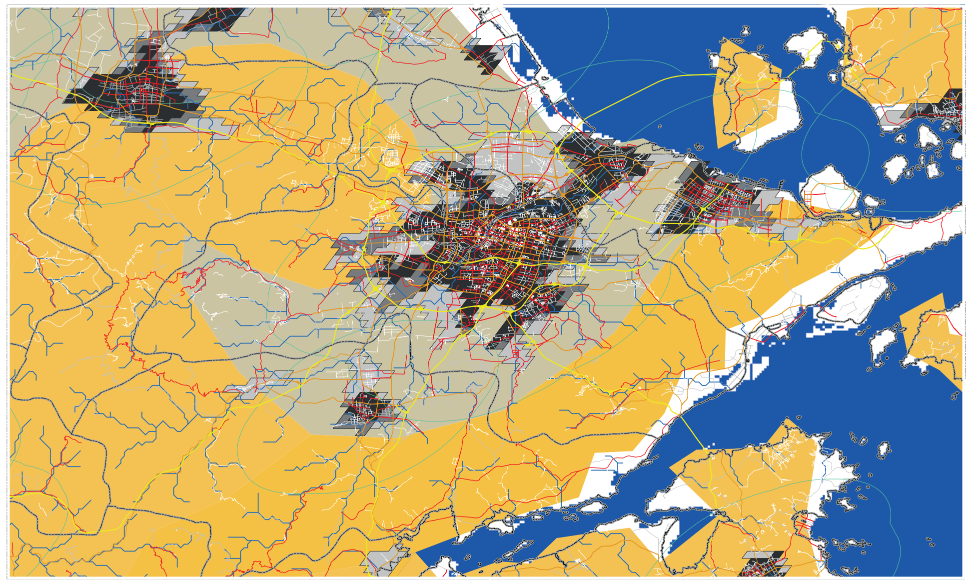
Source: PBL

soil map

legend

- Acrisols
- Cambrisols
- Chernozems
- Podzoluvisols
- Rendzinas
- Ferrasols
- Gleysols
- Phaeozems
- Lithosols
- Fluvisols
- Kastanozems
- Luvisols
- Greyzems
- Nitosols
- Histosols
- Podzols
- Arenosols
- Regosols
- Solonetz
- Andosols
- Rankers
- Vertisols
- Planosols
- Xerosols
- Yermosols
- Solonchaks
- S2-3a
- W2-a

0 25 km N



Source: PBL

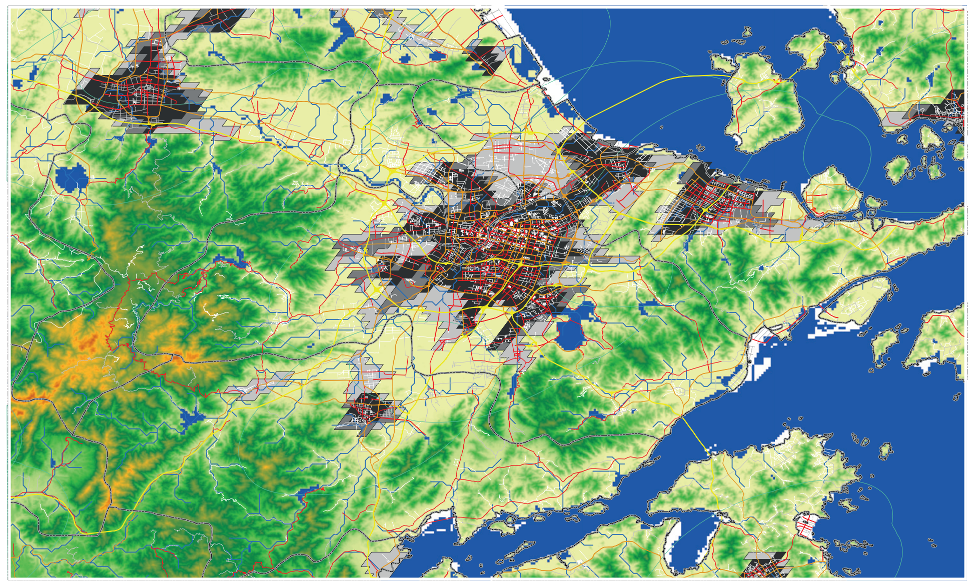
elevation map

legend

height

-428 m +8790 m

0 25 km N



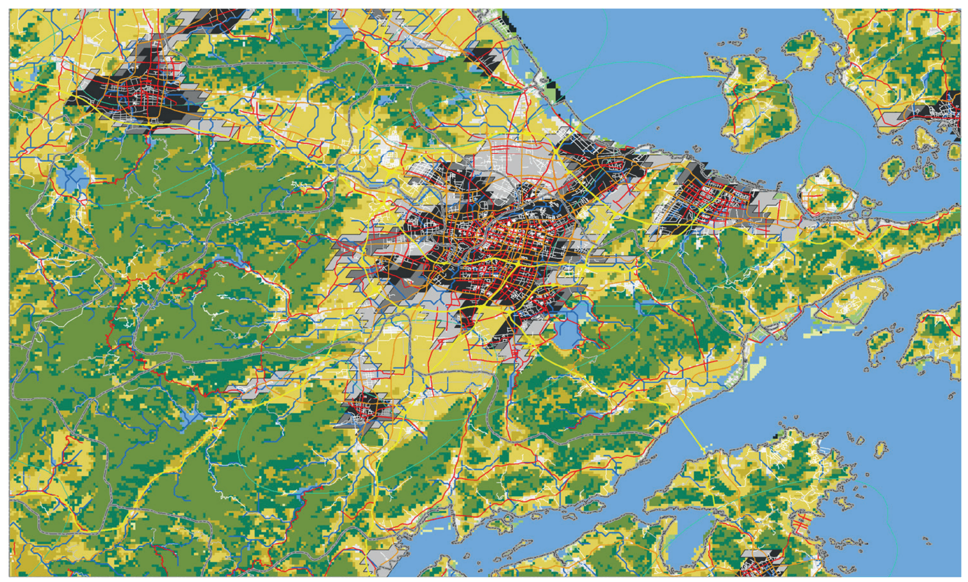
Source: PBL

land-use

legend

- water
- urban area in 1990
- urban area in 2000
- urban area in 2015
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

0 25 km N



Source: PBL

The key to the Sponge City concept is to combine land-use planning, urban water-resource management, urban flood and climate risk mitigation, ecological enhancement and through that improve the living environment. Since the implementation of the Sponge City concept in Ningbo, the water quality in urban catchments and rivers have been improved. Nutrient levels have reduced and waterlogging has been alleviated. The addition of green recreational spaces like the Eco-corridor in Ningbo East Town has succeeded in increasing the capacity to store and treat surface water, while also providing multiple co-benefits as a recreational space and urban 'green lung' (Chang, 2015).

The Sponge City concept is not new in Chinese "water towns" like Ningbo, thus builds on existing practices of water management. These are the seminatural channel networks that divert freshwater from upstream catchments for municipal use and irrigation of wetlands and rice paddies to increase agricultural productivity while mitigating flood and drought risks (Tang et al, 2018). In the Ningbo area the density of this existing water network was increased by reconnecting old waterways with newly installed Blue Green Infrastructures (like urban forests, bioswales, wetland cascades, natural creeks and rivers, etc.). The location of developments that were supported in Ningbo ranged from city centers in new towns to peri-urban areas (Griffiths et al, 2019).

The Ningbo Sponge City Program uses hybrid infrastructures to effectively treat urban stormwater discharge and runoff. However recent experience has shown that Sponge City measures are not designed for intensive rainstorms (e.g. generated by typhoons) or climatic extremes (high magnitude floods and droughts). This has is that the Sponge City initiative is now seeking to restore surface water storage capacity with infrastructure that will improve surface water infiltration. (Griffiths et al, 2019) Also the lack of hydrological connectivity between new development areas and their boundary conditions (surrounding catchments) has emerged as a common area of concern for the Sponge City initiative. While the national guidelines recommend that flood modelling should be integrated with catchment-scale flood and water resource models, support from central government is focused on urban development, such that integration with the larger catchment planning processes is under-represented. The role of municipal or subprovincial government in creating the link between local-scale drainage schemes and municipal-scale infrastructure will therefore be critical in addressing larger catchment considerations. (Griffiths et al, 2019)

It has been suggested that continued flooding in cities and urban areas may have contributed to reports of continued weak interest in Sponge City Public–Private Partnership (PPP) investments. Zhang et al. (2019) found that inadequate supervision, government intervention, immature law and regulation, project fragmentation and unclear catchment boundaries were the main risk factors affecting PPP investments which might have led to a loss of confidence in the model.

The top-down implementation of the "Sponge City" policy is organized by different governmental sectors without involvement of local communities in decision-making, construction and maintenance (Tang et al, 2018). Though there has been much press coverage, this has resulted from a lack of public awareness and understanding about what Sponge City could contribute to the living environment (Griffiths et al, 2019).

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5. Discussion

In this discussion paragraph the preliminary conclusions derived from assembling the Identification framework, making the longlist and analysis of the case studies are drawn and placed in a larger context. PBL did additional mapping of the land-use change and the administrative boundaries to align the cases in their context.

5.1 Insights from case study long list

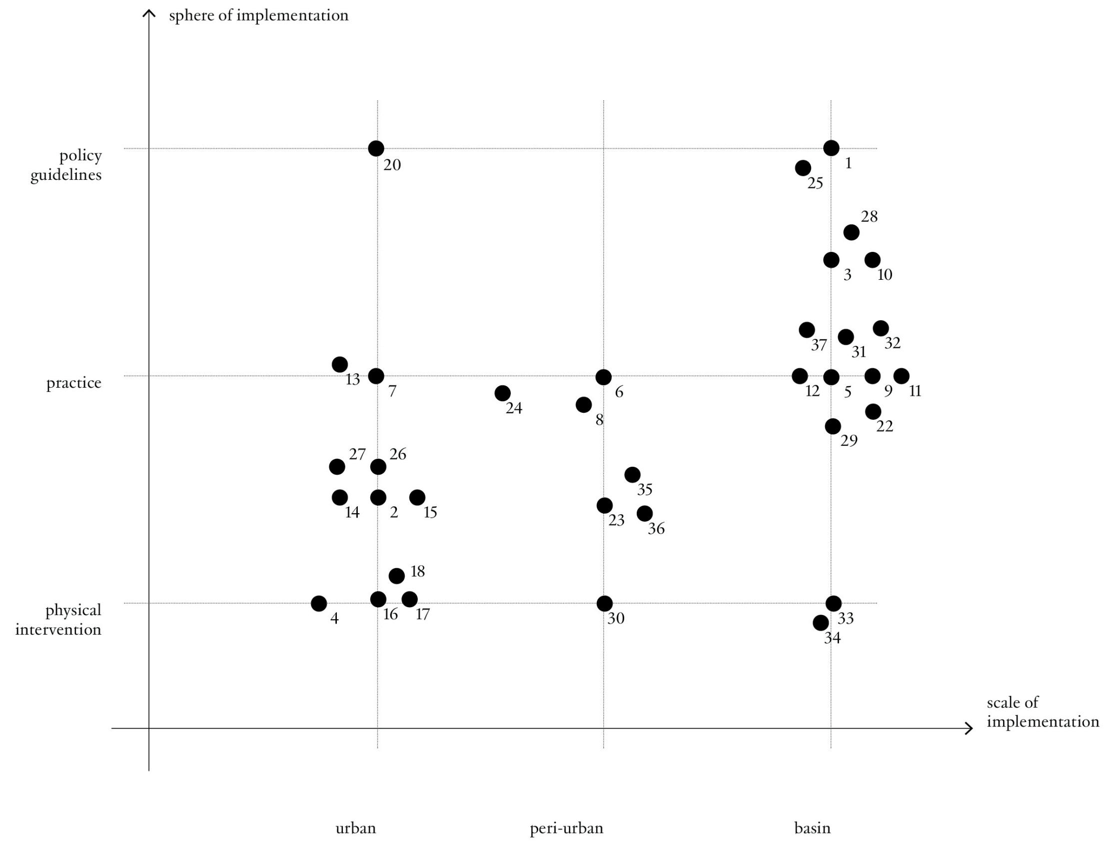


Figure 15
Long list of Case Studies in sphere & scale of implementation matrix in annex II
Source: TU Delft

The literature survey for cases, as described in section 4.2, resulted in a long list of projects that were in the scope of the research. Distributed across the globe, the list gathers 37 projects and/or initiatives taking place in vulnerable geographies and extreme landscapes.

As a general remark, the researchers would like to point out the fact that water-related challenges, in these geographies, take part of a complex system. For example, a community living in a flood prone area, can suffer from water scarcity due to insufficient / inadequate water accessibility, where too much, too little and too polluted happen simultaneously, and sometimes causally given critical social-economic and political contexts.

Under this umbrella, the identified projects and initiatives have the tendency of choosing a starting point (sometimes double) from which to unfold a series of reactions that can result in a better management of the water-related challenges. In this sense, the list was organized accordingly:

• For the water-related challenge of too much water, 13 cases were identified: Kasangulu (Republic of Congo), Bandar Lampung (Indonesia), san Marcos (Guatemala), Arara slum (Rio de Janeiro), Khulna (Bangladesh), Semarang (Indonesia), Ningbo (China), Gorakhpur (India), Nouakchott (Mauritania), Dakar (Senegal), Grand Lahou area (Cote d'Ivoire), Ouidah (Benin), Chennai (India).
• For the water-related challenge of too much & too polluted, 7 cases were identified: Chiang Rai (Thailand), Can Tho (Vietnam), São Paulo (Brazil), Niteroi (Brazil), Recife (Brazil), Rio de Janeiro (Brazil), Dar-es-Salaam (Tanzania).
• For the water-related challenge of being too polluted, 5 cases were identified: Ganjam (India), Asufiti North District (Ghana), Kampala (Uganda), Petropolis (Brazil), Durban-Pietermaritzburg (South Africa).

• For the water-related challenge of too little & too polluted, 7 cases were identified: Indore (India), Peri-urban Great Maputo (Mozambique), Zarqa River Basin (Jordan), Lake Naivasha (Kenya), Bilbeis (Egypt), Cape Town (South Africa), Tana-Nairobi (Kenya).
• For the water-related challenge of too little, 5 cases were identified: Rajastan (India), Shashe, Tuli and Sashne Rivers (Zimbabwe), Burhanour (India), Great Green Wall (Sahel), Mau Forest Complex (Kenya).

Even though a wide range of solutions and approaches can be identified, it is obvious that basin approaches include the collaboration of different scales of implementation (household, community, municipality, nation). The projects have a systemic approach and are therefore designed to tackle the complexity of water-related challenges. In this way, too much, too little and too polluted challenges are tackled in a comprehensive way, including short term responses directed towards a change in more sustained livelihoods that are in tune with the environment.

The *long list* was a research tool in itself that helped spot the different spheres of implementation: policy guidelines, practices and physical interventions. As a research outcome, it drafts an idea of the nature of ongoing projects and initiatives around the globe. As seen in figure 15, the list of projects and initiatives is distributed over the full range of scales of implementation but with a higher concentration of projects on the catchment/basin scale (which tackles at least a pair of water-related challenges in a systematic way) In regards to the sphere of implementation, there is an even distribution of NBS as policy guidelines, practices and physical interventions, coming, most of the times, together in the implementation of structural changes.

5.2 Insights from the case study short list

The six cases represent different climatic conditions, water-related challenges and urbanization rates. On the global scale, visualized in figure 16, it is obvious how especially the Indian, Chinese and Indonesian cases are placed in highly urbanized *regions*. The *local* population growth,especially in the Brazilian, Chinese and African cases, is quite high, whilst in the Indonesan, Indian and Egyptian cases is moderate.

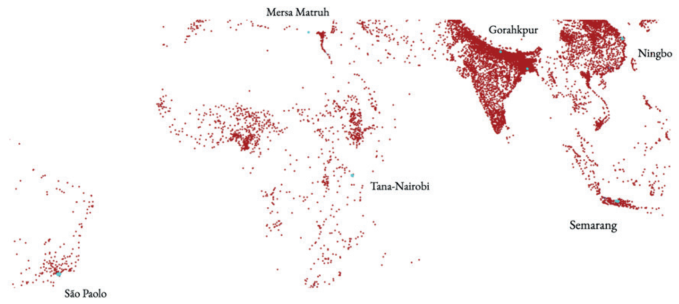


Figure 16
Case Studies in urbanization map
Source: PBL

The analysis on land use change and urbanization trends made by thePBL show how spatial claims compete between the land-use functions: urban use, agricultural production and nature areas (see figure 16, 17 and 18). All cases show rapid and uncontrolled growth that happens at the cost of either natural areas or agricultural areas. The increase of urban areas with higher inhabitant numbers has a double impact on natural areas on a regional scale because of the increase of both urban and agricultural land-use. The higher the density, the more crops, and the more natural areas vanish.

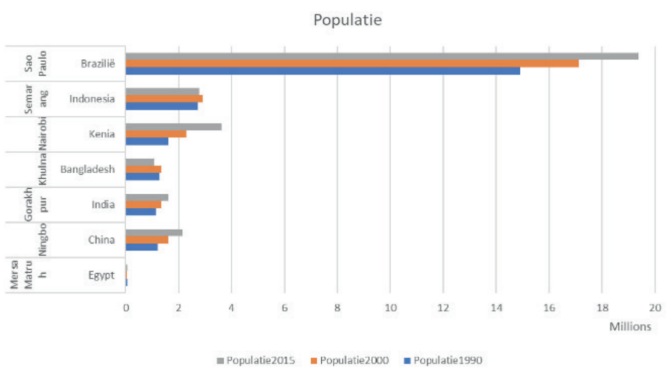


Figure 17
Case Study Population
Source: PBL

Land use
1990

Surroundings 25 km — Surroundings 10 km — City

Gorakhpur, India

Mersa Matruh, Egypt

Tana-Nairobi, Kenya

Semarang, Indonesia

Sao Paulo, Brazil

Ningbo, China

Land use
2015

Surroundings 25 km — Surroundings 10 km — City

Gorakhpur, India

Mersa Matruh, Egypt

Tana-Nairobi, Kenya

Semarang, Indonesia

Sao Paulo, Brazil

Ningbo, China

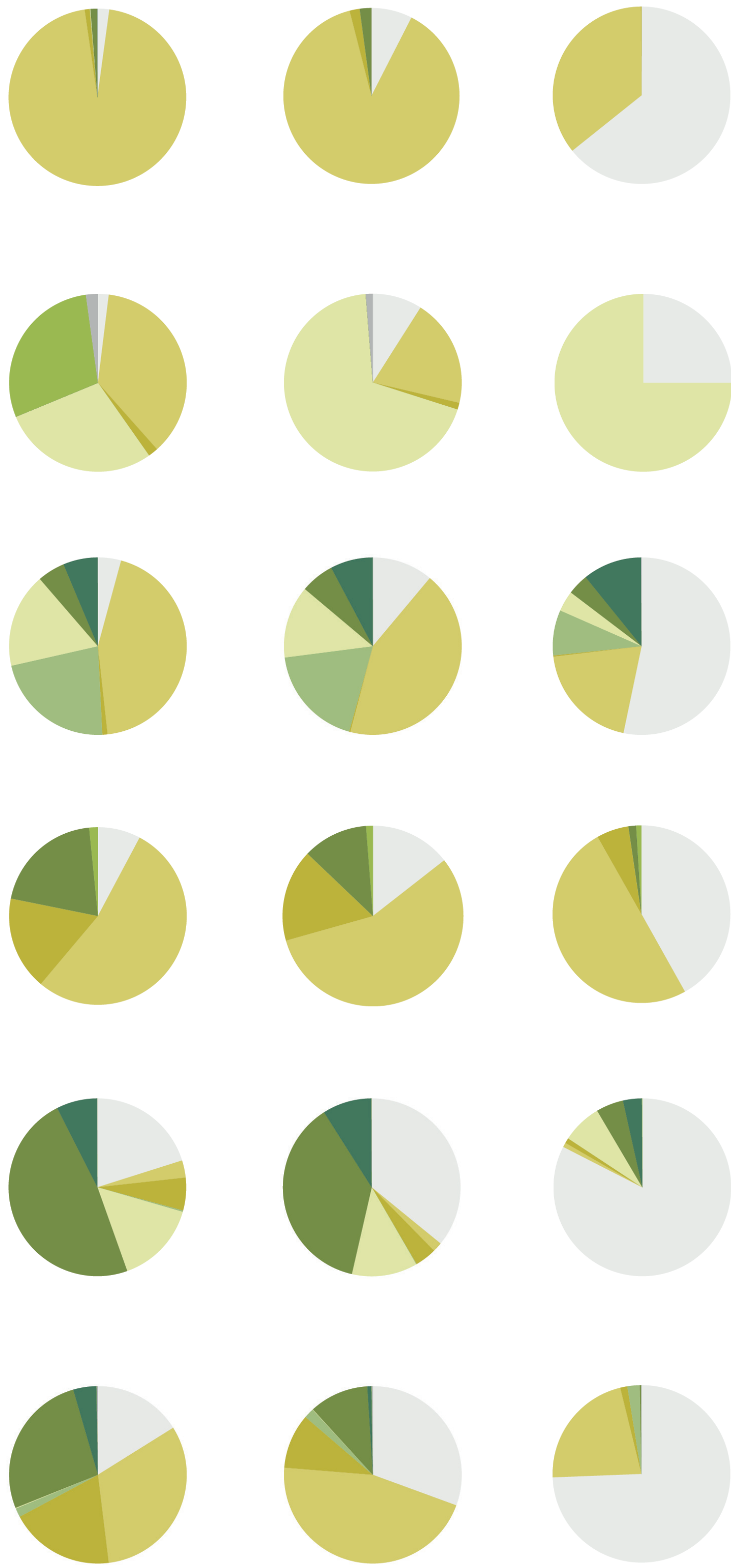


Figure 18
Source: PBL

legend

land use (above)
- urban
- mosaic crops
- crops
- shrubland
- mosaic nature
- trees
- grassland
- sparse vegetation
- other

The overview of the cases is given in Figure 19where the main Research Questions are summarised and a quantitative overview of SDG's shows the impact of the NBS. In general, the cases take a basin approach, addressing the larger water system that also connects urban and peri urban contexts (Bacchin, 2015). The ecosystems involved use natural resources to buffer the water system and reduce the effects of flooding or drought. The capital invested is aimed at activating the social capital within a cooperative approach and in most cases with external financial support from global, national to regional or NGO schemes.

The impact of the projects on the SDGs is quantitatively presented. It must be noted that the need for improvement of specific SDGs (due to specific vulnerabilities) is not taken into account with this approach.

	type of NBS scale, sphere, ecosystem	**capital & cooperation**	**impact** SDGs
Gorakhpur, India Riverine Floods land use change: agriculture -> built up encroachment	urban/peri-urban approach → peri urban & urban problem = peri urban solution micro scale land use change: preserving (increasing) OSM in peri-urban areas as agricultures acting as buffers for riverine floods Dependance on management (urban growth forces)	high use of human capital - knowhow, design, implementation and maintenance phases of the NB fixed economic external support - Rockefeller Foundation - research, tools, training high cooperation - across scales, stakeholders, training platforms, farmers: : ownership - care - replicability, maintenance and evolution	11 /17
Mersa Matruh, Egypt Water Scarcity abandonment	watershed approach → up & downstream problem = upstream solution land use change + structures: wadi restoration through the management and maintenance of agricultures, and water harvesting structures. Dependance on management (delicate environment)	low use of human capital fixed economic external support - World Bank debt conversion low cooperation - the project is "hand in" to the bedouins no reflection on ownership, replicability, maintenance and evolution in time (needed because of the delicate environment)	7 / 17
Tana-Nairobi, Kenya Water Scarcity land use change: forest -> monoculture	watershed approach → downstream problem = upstream solution macro scale framework for land use change: system/framework facilitating/triggering NBS at different scales and types	high use of human capital evolutionary economic internal support - the fund manages, reinvests and attracts more and more public and private investments across scales that result in more jobs and projects very high cooperation - across scales, stakeholders, landowners, families, companies	14 / 17
Semarang, Indonesia Delta Floods land use change: forest -> monoculture	urban/peri-urban approach → peri urban & urban problem = peri urban solution land use change and land reclamation: peri-urban mangrove restoration as buffers for coastal floods. Securing land rights for communities - NBS solution becomes a platform for sustained income.	high use of human capital - learning-by-doing strategy - assessment, design, implementation and maintenance phases of the NB fixed economic external support - high cooperation - across scales - active and intended integration of local communities: ownership - care - replicability, maintenance and evolution	12 /17
São Paulo, Brasil Urban Flooding land use change: urban -> renaturalization	watershed approach → downstream problem = upstream & downstream solution. sub-basin scale framework for re-naturalization through land use change: site specific application of LID solutions.	Use of institutional and local human capital: community cooperation -Local communities cooperate to implement and maintain small scale LIDs. Public-Private funding - Funds raised by NGO from local private companies which directly benefit from program. Financial support from State Fund for Hydric Resources.	9 / 17
Ningbo, China Delta Floods land use change: urban and agriculture -> natural and constructed wetland	urban/peri-urban approach → peri urban & urban problem = peri urban & urban solutions of land use change, land reclamation and retrofitting. macro scale framework for land use change: system/framework for implementing sponge city	low use of human capital Public-private internal economic support - Funded by Chinese central government and Chinese banks with projects being implemented by PPPs. minimal cooperation - Fully implemented and managed by government scales and institutions and regulated by city codes.	8 / 17

Figure 19
Case Study Selection summary
Source: TU Delft

Drivers of the projects

It seems a basic condition that the projects are financially initiated from the outside, although in some cases change is triggered by inside initiatives. Such is the case of Gorakhpur and Tana-Nairobi, where local organizations together with the support of communities promote a change in land practices (with the use of Sustainable Agricultures) triggering the protection of vulnerable areas and the subsequent inclusion of municipal spheres (policy guidelines), and ultimately escalating into international spheres, giving a sound voice and fund to this change.

5.3 Reflection on the Research Questions

(RQ1)Which types of NBS are appropriate in socio-economic unequal urban and peri-urban contexts with extreme water-related challenges?

• The type of climate and the type of land use change are key aspects in framing the problem but also the solution.
• The NBS approach (block, urban, peri-urban, basin approach) can vary according to the location/ geography of felt consequences in relation with the systemic root of the problem.
• The type of NBS (policy guidelines, practices and/or physical interventions) depend on the existence or not of legal and planning frameworks in sensitive areas, and in the spatial configuration of the context shaping and encroaching buffer areas.

(RQ2) Which types of capital and cooperation are appropriate in these contexts?

In these geographies, where structural water challenges are coupled with complex societal and economic problems the how turns out to be the most strategic element when looking at the impact (SDGs) as it can ensure or hinder ownership, care, replicability, maintenance and evolution over time of the NBS.

From the short list, it can be concluded that a successful method to ensure ownership, care, replicability, maintenance and evolution over time of the NBS comes from the following:
• Sustained and retrofitted social capital that includes and sustains livelihoods in time. In this sense, in a sort of soft business case, as seen in the Gorakhpur case (India);
• Sustained and retrofitted financial capital, where business models are developed along with the implementation of NBS at different scales, involving a wide range of stakeholders. In this sense, as seen in the case of Tana-Nairobi, the figure of the fund is key (high cooperation across scales and stakeholders).

5.4 Reflection to identification approach

The design of an identification approach is necessary to be able to understand NBS in their context. The boundary conditions need to be defined and are founded in the relation between humans and nature, namely, the typical geography that stems from that. The identification framework makes it possible to group NBS in their context and build the taxonomy (in figure 10). This is important because every context is very specific whilst the solution can be the same. The framework is not a straightforward checklist but is the assembly of other frameworks or value systems. This is a common aspect to the design approach in which many interests need to be balanced on different scales and the diversity of aspects in relation to the physical environment, ecology and culture in the specific context.

5.5 Relation between GDP and environmental vulnerability: vernacular design

The study into vulnerable geographies in the book Green Cities by Kahn (2006) delivered insight into the relation between GDP and environmental vulnerability. The Environmental Kuznets Curve (EKC) is based on the relationship between per capita income growth and the impact (pollution) on the environment. Market forces play a fundamental role in shaping the urban EKC (Kahn, 2006). Rising income levels lead to changes in the urban economy's consumption and production patterns that may have the unintended benefit of greening the city. Most importantly, people in richer cities are more likely to consume higher-quality products and to work in the service sector. These behavioral changes help offset the pollution-causing effects of increasing scale and put the economy on the downward slope of the EKC. But other varieties of urban growth—notably population and spatial growth–also help identify local environmental quality. The population growth affects urban "greenness," particularly in developing countries where it is commonly accompanied by increasing population density in urban areas.

In the vulnerable geographies that are supported by countries with a high GDP often local knowledge is replaced by knowledge that requires a higher Technological Readiness Level (TRL). This is a methodology developed by NASA (1970s) to estimate the maturity of technologies to enable consistent, uniform discussions of technical maturity across different types of technology.

Blaikie et al. (1992) distinguishes five common trends and shocks in which the utility and maintenance of local knowledge is extremely challenged:

• Areas of very rapid population growth, may require adaptations of new agricultural technologies to increase food production and diversify livelihoods. In this situation local knowledge needs to develop, and adapt very quickly. High population density and reduced field sizes often lead to a reduction in crop diversity in favor of main staple crops. High-yielding crop varieties have the potential negative effects on agrobiodiversity and local knowledge.
• Circumstances in which rapid immigration to a particular area has meant that the repertoires of knowledge for agricultural/pastoral production and environmental conservation, are out of focus with a new set of opportunities and constraints. People find themselves in a new situation, where their local knowledge is no longer relevant.

• Disasters and other extreme events cause a disjuncture, both materially and culturally. Such instances are both opportunistic as well as limiting.
• There are other processes of slower moving environmental changes such as climate change, widespread deforestation or land degradation, that challenge the resilience and adaptability of local knowledge systems.
• Rapid commercialization and economic shocks may also undermine local knowledge. The marketing of local products in a global market will necessarily disconnect the product from its related knowledge context. With the decline in crop diversity, the importance of local knowledge has been reduced (Wooten, 2003).

Balancing the relation between GDP and environmental vulnerability, NBS are supportive in two ways:
1. the use of natural solutions in vulnerable geographies can prevent the environmental impact to go up because of potential mainstreaming of natural processes and ecological restoration ;
2. the level of TRL can be understood differently due to the fact that often natural solutions are also traditional vernacular solutions.

The integration of local and scientific knowledge strengthens the ability of adaptation to respond to more geographic, ecological and socio-economic sensitivities. Also publications like Lo-Tek (Watson, 2020) highlight the key role of vernacular nature based solutions in the maintenance of millennial knowledge. The fact that the wealth in 'modern' societies and physical appearance or technologies (consumerism) are strived after by following economies is a form of obstruction for implementing nature based solutions that are vernacular.

The most illustrative example of replacing vernacular with 'moder' can be found in Thailand. Two of the largest rivers, Chao Phraya and the adjacent Mekong, have abundant water but the major usage is for agriculture. The withdrawal of water for irrigation, especially for wet-rice cultivation, and its release during harvesting has, first, increased the fluctuations on the supply side of the water balance equation, and, second, the released water is often contaminated with fertilizers and pesticides used in agriculture. In either case, the problem is not simply a matter of deduction of consumptive use from runoff. It is more complex and is related to the land use pattern in the river basins, where the urban enclaves generally receive the brunt of the problems because of their location downstream (ENW, 2012).

Large parts of the Chao Phraya river basin have urbanized rapidly over the past decades. Where once rice fields and marshy areas determined the landscape, now a patchwork of larger and smaller cities, industrial estates, suburban residential estates, agricultural areas exists next to still unused, mainly swampy land. Especially the southern part, where Bangkok is located, is highly urbanized. Most of the urbanization is initiated and realized by private parties: developers, businesses and individual households (Askew, 2002; Douglass and Boonchuen, 2006).

The major current problems concerning flooding occur also due to the fact that people do not want to live in houses on piles any more. The vernacular Liquid Perception (Thaitakoo & McGrath, 2010) in which urbanisation was also in harmony with the natural cycles and dynamics of the water, is replaced by a Solid Perception in which urban use is blocking the dynamics of water. People like to live in ground bound houses that take the storage capacity out of the landscape upstream. At the same time the government is building a concrete dike infrastructure along the (urban) rivers to prevent flooding which actually reduces the storage capacity of the river.

The 'Monkey Cheek' project is a study that resulted from the 5th International Conference on Sustainable Energy and Environment 2014 (Shinawatra, 2014). It proposes the creation of new lagoons in the Gulf of Thailand, which can accumulate water from the rivers even during high tide. During low tide the basin can gradually be emptied into the sea. It involves the Liquid Perception in which the landscape and urbanization is adaptive to the changing water dynamic because of climate change.

The term 'vernacular' is originally related to the native language of a particular country, region or locality. Vernacular design is characterized by the fact that humans had to work with the matter at hand and respond to the climate or landscape extremes. Over centuries, a trial-and-error evolution was able to produce "vernacular" design solutions that are climatically appropriate, culturally relevant and aesthetically pleasing (Emmanuel, 2012). In fact, our ancestors were able to control the climatic environment in buildings they designed when there were no mechanical systems invented. Vernacular architecture is an architectural style that is based on interrelations between ecological, economic, material, political and social factors (Asquith and Vellinga, 2006) and it provides a good solution to the climatic constraints. History shows that vernacular techniques and materials have been shaped by the local culture, weather and geographical location. The selection of these techniques and materials for such a building is usually dependent on the desired benefits, as well as the local availability of construction materials and skilled labor (Alrashed et al, 2017). Replacing architecture with landscape architecture, vernacular landscape architecture as an approach would involve NBS automatically.

5.6 Relation NBS with Building With Nature

The term Nature Based Solutions is very much aimed at the end result, the solution to a problem. This implies that there is a clear problem that needs to be solved. Especially in aiming for finding synergy with multiple SDGs the cases show that it is not always the 'what' but also the 'how' that has the most impact. The 'how' can be organised through an approach, as mentioned above the landscape approach, Building Back Better or another buzzing concept Building with Nature.

In the Netherlands Ecoshape is an organisation that has developed the concept. On their website the explanation is as follows: *Building with Nature is a design approach to develop Nature-based Solutions for water-related infrastructure such as flood defences, sustainable port development and for the restoration of ecosystems. It uses system understanding and the inclusion of natural processes as core of its solution. It harnesses the forces of nature to benefit the economy, society and the environment. Through the BwN approach sustainable infrastructure can be developed as well as contribute to the Sustainable Development Goals (Ecoshape). Also, interaction with relevant stakeholders, including local communities, is key to successful implementation of Building with Nature. All solutions have in common that they are context-specific, multi-functional, innovative and dynamic, and are based on a landscape perspective.* [2]

[2] see for more information https://www.ecoshape.org/en/the-building-with-nature-philosophy/

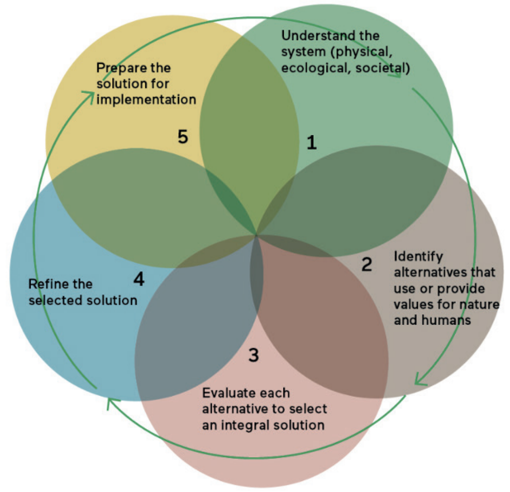


Figure 20
Building with Nature 5 step approach.
Source: Ecoshape

The Building with Nature approach is a philosophy that helps engineers in infrastructure projects not just focus on the solution but to study the larger context of their project. In relation to NBS in vulnerable geographies the identification framework can be considered the same approach in which the steps, presented in figure 20, are presenting the dimension of design in exploring and evaluating alternatives. In that sense also levels in NBS could be introduced: are the solutions supporting the conservation of ecosystems, are they green in the sense that they participate in the ecosystem , or are they maybe grey to support the ecosystems and protect them from human interaction?

5.7 Synergies SDG's

The 'how to implement' NBS turns out to be the most strategic element when looking at the impact (SDG's) as it can ensure or hinder: ownership, care, replicability, maintenance and evolution over time of the NBS.

In finding synergy with the SDG's the purpose of using NBS should be not just solving contemporary problems but creating better conditions for the future. This is also represented in the concept Building Back Better. The UNDRR (The United Nations office for Disaster Risk Reduction) identifies Prevention, Preparedness, Response and Recovery as key components of risk reduction, however, recovery is the final and often least developed part of this framework (UNISDR, 2015). That recovery to the same level is basically a lost chance and that the disaster could also help in improving other sectors was made one of the four priority areas of the Sendai Framework for Disaster Risk Reduction: Enhancing disaster preparedness […] to «Build Back Better» in recovery, rehabilitation and reconstruction (UNISDR,2017).

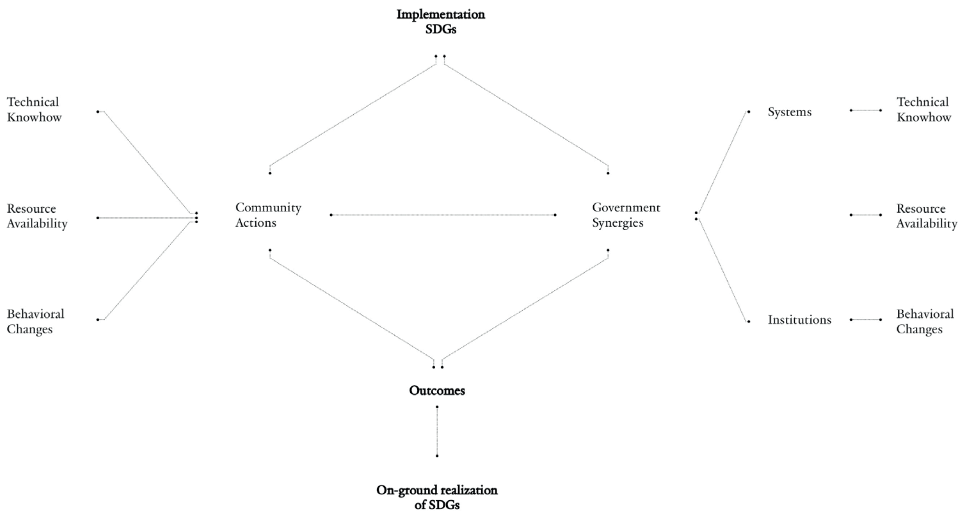
In 2015, the signing of the Sustainable Development Goals, Sendai Framework for Disaster Risk Reduction and Paris Agreement on Climate Change marked a paradigm shift in the way the relationship between society, economy and environment is to be sustained. The development of NBS as knowledge, planning, implementation and operational framework followed this change of paradigm, inspired from nature's performative capacity to adapt and evolve in response to environmental and climatic change.

NBS, being multi-purpose actions, have the potential to help achieve and localise SDGs by incrementally enhancing environmental, economic and social conditions at site, specially when SDGs are defined as target objectives during the conceptualisation and design phase of NBS. The set of co-benefits brought by NBS, for example, biodiversity conservation, flood and drought risk management, microclimate regulation, improve health and well-being, enhance the robustness and affordance of places and their capacity to recover, adapt, and sustain growth. The capacity to develop in face of incremental or disruptive change is linked to the quality of ecosystems, namely, their potential to adapt, regenerate and sustain ecological performance in time. The structuring and mainstreaming of community-led NBS initiatives in governmental plans and programmes are likely to restore such potential in the short- and long-term: In the short-term, they provide cost-effective and no-regret solutions that help coping with urgencies at a local level. In the long-term, nature's robustness, redundancy and resourcefulness are likely to restore resilience (resilient behaviour in healthy and well-functioning ecosystems) in light of socio-economic, demographic and climatic uncertainties.

Nature Based Solutions are a crucial change in orientation in the envisioning and implementation of tactics (design and engineering solutions) and strategies (planning, governance and management frameworks) in achieving sustainable development goals, disaster risk reduction and climate adaptation. Identifying the role for communities, private sectors and governmental agencies in the development of tactics and strategies for NBS in vulnerable geographies is a fundamental step to realise and achieve SDGs. The transition from the Millennium Development Goals (MDGs) to the Sustainable Development Goals (SDGs) starting in 2015 called for this change in orientation in global development - to be achieved via synergies and reciprocities between societal, economic and environmental actions. SDGs targets need to be localised via the identification of design units (spatial and temporal scales), financial instruments, implementation actions, management and monitoring schemes. Therefore, for adaptations to be transformative - leveraging behavioural change via NBS - tactics and strategies should be scalable and sensitive to ecological, cultural and social complexities at site.

The recognition of local specificities and the role of different actors and stakeholders help determine the means of implementation of NBS to achieve SDGs, situating practices to link global goals to local communities. The appropriation and sense of ownership of NBS by local actors and stakeholders is a critical catalyst for the development and mainstreaming of transformative adaptations to overcome societal challenges. Acharya et al. (2020) argued the role of NBS as transformative adaptation practices, enabling fundamental shifts in state and interactions of society and nature. In this, the active participation of local communities is crucial to ground and route NBS in relation to practical knowledge, culture and available expertise, whereas government bodies via policies, strategic and operational frameworks structure, upscale and mainstream such practices. According to the authors *"behavioural transformation focuses on the willingness and acceptance by the communities to take up NBS in local actions, on the other hand it aligns with the exemplary management skills and competencies of the government"* (Acharya et al., 2020, p. 442).

Figure 21
Factors associated with realization of SDGs.
Source: Acharya et al. (2020)



Realising SDGs by mainstreaming NBS in vulnerable geographies is a time and action-based process that calls for a situated and sensitive approach to culture and local knowhow. It involves capacity building programmes for the building of trust and ownership of solutions between local communities and governmental bodies. In such an effort, the use of indicators to measure and monitor progress is crucial to quantify and qualify the achievement of SDGs, informing an integral management of assets, resources and skills. Measurable systemic changes enabled by NBS in the releasing of SDGs are: (a) future proofing adaptive strategies; (b) addressing root causes of vulnerability; (c) social and economic uplifting; and (d) situating design, engineering and planning practices by working with and grounding solutions based on natural resources and processes, social and technical knowledge at site.

Sustainable development goal	Related DRR orCCA target	How NbS will help to achieve the goal/target
Goal 1: *End poverty in all its forms everywhere*	*Target 1.5*	*NbS promotes protection against climate-related disasters and extreme events, climate regulation, providing alternative sources of income through ecosystem-based adaptation and ecosystem approaches*
Goal 2: *End hunger achieve food security and improved nutrition and promote sustainable agriculturee*	*Target 2.4*	*Promoting ecosystembased adaptation, ecosystem approaches promoting and ecological restoration using the provisional and regulatory ecosystem services*
Goal 3: *Ensure healthy lives and promote wellbeing for all at all ages*	*Target 3.d*	*Water quality enhancement through wetlands (ecosystem approaches), harnessing the regulating ecosystem services*
Goal 4: *Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*	*Target 4.7 and 4.a*	*Cultural ecosystem services provide a scope to enhance personal and spiritual growth for effective and safe learning environment*
Goal 6: *Ensure availability and sustainable management of water and sanitation for all*	*Target 6.3, 6.4, 6.5, 6.6, 6.a and 6.b*	*Utilising all the four types of ecosystem services and application of combinations of ecosystem-based management approaches, ecosystem-based adaptation and ecological restoration strategies, NbS can address the targets of goal 6*
Goal 9: *Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation*	*Target 9.1 and 9.a*	*Natural infrastructures and green infrastructures based on ecosystembased adaptations also promote climate resilient infrastructure*

Sustainable development goal	Related DRR orCCA target	How NbS will help to achieve the goal/target
Goal 11: *Make cities and human settlements inclusive, safe, resilient and sustainable*	*Target 11.1, 11.3, 11.4, 11.5, 11.b and 11.c*	*Ecosystem services contribute to thriving cities during times of stability, particularly through the provision of cultural ecosystem services that bring social, cultural and community benefits and well-being. Nature-based solutions and urban green spaces provide the location for recreation, social interaction, building community cohesion and contributing to physical and mental health and well-being (Viniece and Omoshalewa 2019)*
Goal 13: *Take urgent action to combat climate change and its impacts*	*Target 13.1, 13.2, 13.3, 13.a and 13.b*	*Nature-based solutions promoting green and blue urban areas have significant potential to decrease the vulnerability and enhance the resilience of cities in the light of climatic changes (Kabisch et al. 2016)*
Goal 14: *Conserve and sustainably use the oceans, seas and marine resources for sustainable development*	*Target 14.2*	*NbS offers coastal protection through ecosystem-based adaptation measures, ecological restoration measures as well as promoting protected areas for sustainable use and to restore and protect the ocean waters and coastal resources*
Goal 15: *Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*	*Target 15.1, 15.2, 15.3, 15.4 and 15.9*	*Ecosystem-based adaptations, ecosystem-based management practices, protected areas, ecosystem restoration, landscape restoration all these approaches are well aligned to address the challenges of land degradation, halt biodiversity loss, sustainable use of land systems, effectively manage forest and associated landscapes*

Adapted from Prime Minister's Agenda 10: India's Disaster Risk Management Roadmap to Climate Resilient and Sustainable Development (pp. 21–22), by Gupta et al. 2016, New Delhi and Core principles for successfully implementing and upscaling Nature-based Solutions by Cohen- Scaham et al. 2019, Environmental Science and Policy, pp. 20–29 copyright 2019 by the Authors with permission

6. Conclusions

6.1 Specific and general criteria in the selection of NBS appropriate in socio-economic unequal urban and peri-urban contexts with extreme water-related challenges.

The baseline conclusion of this report is that globally the relation between people and their environments is defining for their state of development. The first defining aspect of this relation is the climate and landscape typology. Having too much, too little or too dirty water is the result of these typologies and the natural system. The second aspect of this relation is the impact of the fertility of the landscape and climate typologies on the human system: it defines prosperity. When this is low, usually the welfare is as well, the governance is weak, inequalities are extreme and the Technological Readiness Level (TRL) also low. This means that 'the how to implement', and 'what to implement' is not comparable to countries that have high welfare, strong governance, are economically balanced and have a high TRL level.

Beyond this the impact of human interaction with the landscape, land use and urban systems in place, are not comparable. Both the type of climate and the type of land use change are key aspects in framing the problem but also the solution. The NBS approach therefore can vary according to the location and geography of felt consequences in relation with the systemic root of the problem. Thus, the typology of NBS depends on the existence or not of legal and planning frameworks in sensitive (vulnerable) areas, and in the spatial configuration of the context shaping and encroaching buffer areas.

Conclusions on 'the how to implement':

- Definition of the adaptation typology
- Insight in the structural water challenges and complex societal and economic problems → the "how" turns out to be the most strategic element when looking at the SDGs, as it can ensure or hinder: ownership, care, replicability, maintenance and evolution/transformation over time
- Sustained and retrofitted social capital = by including communities' cooperation
- Sustained and retrofitted monetary capital = by developing business models, figure of funds
- High cooperation across scales and stakeholders

Conclusions on 'the what to implement':

Necessary is the analysis on the adaptation typology and spatial configuration of
- climate typology + land use change → problem & solution (reversing, hybridizing land use)
- NBS approach/scale: felt consequences = source of the problem?

Necessary is the definition of the approach:
- watershed approach → most strategic when dealing with water scarcity downstream and riverine floods
- peri-urban approach → most strategic when dealing with coastal and pluvial floods

Definition of the NBS typology:
- physical intervention → buffer areas - spatial configuration and composition of elements (for example: the type, diversity, scale size and level of connectivity between green and blue patches and corridors)
- community practice → ensuring continuity, replicability (adaptation typology)
- policy guidelines → ensuring continuity, replicability (adaptation typology)

6.2 Main differences in the selection, implementation and impact of NBS in the studied geographies in comparison with NBS in Europe (Naturvation)

- Water-related challenges are structural to livelihoods, extreme poverty and survival
- Structural water challenges are coupled with complex societal and economic problems
- Lack/insufficient legal frameworks that acknowledge and protect the water cycle, lead to the necessity of NBS as policy guidelines
- Limitation and uncertainty of surface water availability in extreme climates can be potentially addressed by the decentralization of water harvesting practices suited to local rainfall frequencies and settlements
- Long-term sustained impacts come with the involvement of the three spheres of the solution -policy guidelines, spatial interventions, community practices. When areas are strategically addressed in planning frameworks, social behaviours and livelihoods accounted for, affected communities are likely to be better equipped to adapt and thrive.. This reinforces the necessity for a systemic approach, balancing the choice of solutions and their implementation time across design units and scales of influence.

7. Recommendations

7.1 Connection to PBL projects.

This literature research was performed to connect several projects within in PBL:

The Geography of Future Water Challenges (that is supported by the quantitative study by IHE)
This research is in the second phase, the first phase resulted in a publication that shows that, without improved water management or adaptation to climate change, the global sustainability goals cannot be achieved. The project highlights the urgent need for an integrated approach to limiting climate- and water-related risks. Using maps and infographics, The Geography of Future Water Challenges shows the water-related challenges of tomorrow, under a business-as-usual scenario.[3]
Alignment with the future research recommendations can be established.

[3] see for more information https://www.pbl.nl/en/publications/the-geography-of-future-water-challenges

Post 2020 Biodiversity
This policy brief describes the crucial role cities hold for realising global goals for nature. Whether or not the global community is able to achieve its goals for biodiversity over the next three decades will critically depend on how both the threats and opportunities of living on an urban planet are addressed. Advancing transformative change for biodiversity will require municipal authorities and a range of other urban actors to mainstream action on both the direct and indirect drivers of biodiversity loss — from land-use change to sustainable production and consumption — while ensuring that the value of nature and its contribution to people and society is widely recognised across urban communities. In this policy brief, we set out how we can harness urban opportunity in the post-2020 Global Biodiversity Framework (GBF).[4]
Alignment with the future research recommendations can be established.

[4] see for more information https://www.pbl.nl/en/publications/realising-the-urban-opportunity-cities-and-the-post-2020-biodiversity-governance

Landscape approach
Driven by the surge of interest and commitment to landscape level initiatives by international organizations like FAO and CGIAR institutes and the Dutch government, PBL performed a study aimed at expanding knowledge and understanding of the success factors, barriers and stakeholders that influence inclusive and sustainable development on a landscape level. Over the past decades, the landscape approach has been put forward as a possible decision support solution for several development issues (often referred to as competing claims) that converge on a landscape level. The landscape approach aims to integrate the objectives of different stakeholders at landscape level, in order to establish long-term sustainable growth. The pursued objectives are those of sustained economic and social development, combined with local biodiversity conservation. Thus, landscape approaches could lead to improved cross-sectoral decisions that are better than the sum of actor- and sector-specific solutions. [5]
Alignment with the future research recommendations can be established.

[5] see for more information https://www.pbl.nl/sites/default/files/downloads/PBL_2015_The_Landscape_Approach_1555.pdf

Naturvation
NATure-based URban innoVATION is a 4-year project, funded by the European Commission and involving 14 institutions across Europe in the fields of urban development, geography, innovation studies and economics. It studies and evaluates NBS in the European connext. [6]
Alignment with the future research recommendations can be established.

[6] see for more information https://www.pbl.nl/blogs/in-gesprek-over-stedelijke-natuur

7.2 Further research

- The long list of projects offers valuable material and information that can be used for analysis in different ways. Future steps would be to study them as the short list analysed in this research, cluster and develop a comparative analysis on the different planning and design frameworks and practices used and their implementation instruments and levels.
- The identification approach gives a qualitative approach to the study of NBS. This approach can be translated into indicators that could serve well for the IHE study.
- Further development of a qualitative and quantitative method to measure how does the NBS implemented impact different SDGs
- Spatial projective analysis of the NBS in the selected locations (short list), this would serve the development of a set of NBS in the matrix of climate, landscape and adaptation typologies
- The evaluation of the cases is done on a limited set of capitals worldwide, this could be expanded
- The identification framework could be transferred into an approach like the 'vernacular landscape approach NBS' or 'Building with Nature in Vulnerable Geographies'.
- Evaluation tools for NBS implementation can be developed on the basis of the revision of ecosystem services evaluation tools like TEEB and BEST, see how those could be 'adapted' to the specific context of vulnerable geographies.
- Guidelines for urban planning can be developed on the basis of the identification framework related to the i) Context to water stress, ii) Water stress to NBS, iii) NBS implementation & Impact.

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Appendix

Annex I
Literature review analysis

year	article	authors	highlights/interesting remarks
2018	Nature-Based Solutions for agricultural water management and food security	Sonneveld, Merbis, Alfarra, Ünver, & Arnal	*In summary the paper studies the role that nature based solutions can play in making agriculture more productive while maintaining and preferably strengthening the integrity of the ecosystems from the lens of water resources management. It covers a synopsis of 20 cases as the basis for an assessment of the possible reasons for success and failure of NBS. The NBS case studies were selected for their contribution to water management interventions.* -(Definition of NBS): In principle, NBS aim to contribute to the improved management of water resources at both the micro and macro levels. NBS can involve conserving or rehabilitating natural ecosystems and/or the enhancement or the creation of natural processes in modified or artificial ecosystems. Moreover, they support a circular economy that advocates greater resource productivity while reducing waste and avoiding pollution through reuse and recycling processes. NBS are consistent with numerous religious and cultural beliefs that advocate equity between man and nature. Although NBS are based on sound science and economics, they may represent a bridge between traditional and modern paradigms. NBS have a tendency to be in harmony with customary laws and local and traditional knowledge that are consistent with the human rights-based approach for water resources. -Eggermont et al (2015) suggests 3 NBS typologies that clarify trade-offs between the degree of engineering/intervention in the ecosystem and the delivery of ecosystem services for the stakeholders involved. -Successful case studies point to a satisfactory understanding of the functioning of ecosystems and the importance of multi-stakeholder platforms, well-identified funding schemes, and realistic monitoring and evaluation systems. -*Failure* cases were attributed to a lack of understanding of the functioning of ecosystems and ecosystem services combined with a top-down planning *without involving local communities and knowledge* and sometimes also combined with armed conflicts that hindered the empowerment of people to take matters in their own hands. -NBS comprise closely related concepts such as improved *water use efficiency, integrated watershed management, source-to-sea initiatives, ecosystem approaches, eco-hydrology, agroecology* and, *green and blue infrastructure development* -The evaluation of NBS interventions takes place in the basis of: financial mechanisms and rewarding schemes, transdisciplinary and institutional collaboration -SDG's related to NBS: (1) no poverty, (2) zero hunger, (6) clean water and sanitation, (13) climate action, (15) life on land *-Check table 2. Inventory of case studies for: South Africa, Nigeria, Kenya, Ecuador, Tanzania, El Salvador, Iran, Burundi, Nepal, Egypt, South Sudan. Colombia, Perú, The Philippines and Brazil*
2018	Nature-based Solutions for Water.	UN Water	*The 2018 edition of the World Water Development Report (WWDR 2018) seeks to inform policy and decision-makers, inside and outside the water community, about the potential of nature-based solutions (NBS) to address contemporary water management challenges across all sectors, and particularly regarding water for agriculture, sustainable cities, disaster risk reduction and water quality. (...)* -The report classifies the use of NBS for managing: *(chapter 2) water availability,* (e.g.: managing water runoff + storage / "conservation agriculture" minimizing soil disturbance / urban setting: enhancing collection). *(chapter 3) water quality and* (e.g.: Water protection - Regulate water quality / reduce sediment load / NBS for runoff / urban (not equal to) industrial treatment of water). *(chapter 4) water-related risks, variability and change* living with floods / NBS in Agriculture: important benefits. -The report distinguishes the implementation of NBS at *basin scale* and *urban scale* -Establishes the potential of NBS for water and sustainable development in achieving the 2030 Agenda for Sustainable Development with special attention to food security (the most critical factor in poor underdeveloped countries) -See table 1.2 Green Infrastructure solutions for water resources management according to primary service to be provided (water availability, water quality and moderation of extremes -riverine flood control, urban stormwater runoff, coastal flood-), green infrastructure solution, location (watershed, floodplain, urban, coastal) and corresponding grey infrastructure solution (at the primary service level). -Evolving approaches to the water-ecosystem nexus. Emphasis has shifted from looking at impacts on ecosystems to managing ecosystems to achieve better management objectives (see figure 1.5)

year	article	authors	highlights/interesting remarks
			Benefits of NBS4W: Energy Security / Health / Food & Socio-Envi. Dev. Scale: From dry toilet to conservation agriculture Obstacles for NBS4W: Lack of Knowledge / Capacity / Data+Info about NBS4W Mechanisms to implement: Payment schemes for env. Services / Green Bonds World water factors: Demands / Availability / Quality / Extreme events NBS4W manage: Precipitation / humidity / water storage / infiltration / transmission - Brings the concept of "precipitation shed" rather than just watershed in order to consider a larger extent of the territory when evaluating solutions for water management. - NBS capacity is enhanced when associating green-grey solutions - General Limitations for NBS4W solutions: 1. Lack of understanding on how to integrate green+grey 2. Lack of capacity to implement 3. Lack technical guidance, tools + approaches 4. Lack of impartial + robust assessment of current NBS 5. Lack of an understanding on what ecosystems can achieve. *Examples of NBS4W management for water availability:* *2.1. Sand dams in dry rivers, Zimbabwe, Africa.* Rivers in semi-arid environments (sand rivers) form shallow groundwater reservoirs, recharged when rivers flow. Even after dry seasons, seasonal rivers contained sufficient water for irrigation. Walls across the river in the sand, heighten the river bed and increase the sediment thickness, increasing volume and accessibility of water stored. Allows farms to extend the cropping season into dry periods and have a second harvest. Requires sustainable use as to not stress the system and community monitoring ensuring critical information on actual groundwater levels Potential for vast implementation in semi-arid environments. *2.2. Landscape Restoration. Rajasthan, India* Severe droughts caused by over exploitation and successive low rainfall. Reduction of groundwater extraction was enforced. NGO + local women leadership supported landscape-scale restoration for local water cycles. Small scale harvesting structures + regeneration of forests and soils. Very successful, increased farmland and return of wildlife. *2.3. Conservation Agriculture (Various locations)* Minimizing soil disturbance / maintaining a continuous soil cover or organic mulch and/or plants / cultivation of diverse plant species (can include annual + perennial crops, trees, shrubs and pastures) Economic benefits established in Latin America and Africa (smallholder) and large scale production systems in Brazil and Canada. Undertake is variable between regions. *System of Rice Intensification. Origin: Madagascar* System for re-establishing the ecological and hydrological function of soils based on modifications in standard crop and water management practices. Increase resilience and reduce greenhouse gas emissions. *Landscape Restoration. Tana River, Kenya* Accelerated erosion due to agriculture and geomorphology conditions. Reforestation and riparian management among other measures have helped reduce sedimentation in water reservoirs. *Watershed Services. Itaipu, Brazil* More efficient soil management by agriculture increases reservoir efficiency and life expectancy of Itaipu Dam. *Examples of NBS4W management for water quality:*

year	article	authors	highlights/interesting remarks

Table 3.1 - Categories of common source water protection activities
Targeted Land protection: preventive measure that reduces risk of adverse environmental impacts
Revegetation: through plantation or natural regeneration
Riparian restoration: critical for survival of water species and climate regulation

Agricultural Best Management Practices (BMPs):
Ranching best management practices (BMPs)
Fire risk Management: Controlled cut
Wetland restoration and creation:
Road management:

Examples:
Water Funds - Quito (Ecuador) & Nairobi (Kenya)

Table 3.2 Water quality in the SDGs

SDG	Target	
SDG 6 Water and sanitation	6.1	Achieve universal and equitable **access to safe and affordable drinking water** for all
	6.2	Achieve **access to adequate and equitable sanitation** and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations
	6.3	**Improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally**
	6.6	**Protect and restore water-related ecosystems**, including mountains, forests, wetlands, rivers, aquifers and lakes
SDG 1 Poverty	1.4	Ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as **access to basic services**, ...
SDG 2 ... promote sustainable agriculture	2.4	... ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems ... and that progressively improve land and soil quality
SDG 3 Health	3.3	End the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, **water-borne diseases** and other communicable diseases
	3.9	Substantially reduce the number of deaths and illnesses from hazardous chemicals and air, **water and soil pollution and contamination**
SDG 7 Clean energy	7.3	Double the global rate of improvement in energy efficiency
SDG 9 Build resilient infrastructure...	9.4	... upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes ...
SDG 11 Sustainable cities	11.3	... enhance inclusive and sustainable urbanization ...
	11.6	... reduce the adverse per capita environmental impact of cities ...
SDG 12 Sustainable consumption and production	12.4	Achieve the environmentally sound management of **chemicals and all wastes** throughout their life cycle, in accordance with agreed international frameworks, and significantly **reduce their release to air, water and soil** in order to minimize their adverse impacts on human health and the environment
SDG 14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1	... prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution
SDG 15 Ecosystems	15.1	Ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

Source: Adapted and updated from UNESCO (2015a, p. 7).

Examples of NBS4W management for water-related risks, variability and change:

Examples of *implementation at basin scale:*
1. PES scheme at lake naivasha, Kenya
2. Upper Tana-Nairobi Water Fund
3. The Quito water conservation fund
4. *CHAO Phraya River Basin, Thailand:* UTFI Concept
5. *Hima systems revival, Jordan:* land preservation from occupation for water management.

year	article	authors	highlights/interesting remarks
			Examples of *implementation at urban scale:* 1. Constructed wetlands in Egypt and Lebanon (water quality) 2. *Compensation Mechanisms for Ecosystem Services Law, Peru:* 12 cities have approved tariffs that include watershed investments.
2018	Urban Nature Atlas: A database of nature-based solutions across 100 European cities	Almassy, Pinter, Rocha, Naumann, Davis, Abhold & Bulkeley	-NATure-based URban innoVATION (NATURVATION) is a 4-year project, funded by the European Commission and involving 14 institutions across Europe in the fields of urban development, geography, innovation studies and economics. - According to the NATURVATION project, nature-based solutions are deliberate interventions that can be inspired or supported by nature in addressing urban challenges, such as climate change mitigation, water management, land-use and urban development (Bulkeley et al, 2017). -Projects included in the Urban Nature Atlas had to fulfil the following criteria: (1)Address various urban societal challenges (e.g. climate mitigation, water management, coastal protection, human health and recreation, social justice); (2)Have 'function-enhancing' features, that change or enhance the function of an area/structure; (3)Use nature as an inspiration to address an urban problem was either a physical intervention or a discursive one. (3)Applied indicators for the city selection included demographics, city size, unemployment, proportion of green space, access to green areas in Europe's cities, climate risk and vulnerability. By choosing a diverse sample of cities, the project aimed to analyse which types of nature-based solutions are being implemented, how they are being delivered and the issues they are seeking to address, what is their type, form, function and distribution. *The urban setting of studied projects per ecological domains are:* - parks and urban green areas → large urban parks or forest, pocket parks/neighbourhood green spaces, botanical garden, green corridor - grey infrastructure with green features → alley and street trees/edges/greens, railroad bank and tracks, hourse gardens, green playground/school grounds, institutional green space, green parking lots, riverbank greens - blue areas → lake/pond, river/stream/canal/estuary, delta, sea coast, wetland - allotments and community gardens - external building greens → allotments, community gardens, horticulture - green areas for water management → rain gardens, swales, sustainable urban drainage systems - derelict areas → abandoned and derelict spaces with growth of wilderness or green features - green indoor areas → indoor vertical greeneries, atrium
2013	The role of local knowledge in adaptation to climate change	Lars Otto Naess	-Evidence from recent research suggests that local knowledge may contribute to adaptation to climate change in a number of ways -The article shades light on some of the key potentials and challenges for the application of local knowledge for adaptation, drawing on recent studies as well as findings from demi-arid Tanzania. - The article illustrates how the role of *local knowledge at the local level is determined by interaction between informal and formal institutions at the local level*
2018	The role of Indigenous and Traditional Knowledge in ecosystem-Based Adaptation: A review of the literature and case studies from the Pacific Islands	Nalau, Becken, Schliephack, Parsons, Brown, Mackey	-Community-based projects can strengthen those ecosystems that deliver critical services to communities and in doing so enhance community resilience. - The inclusion of indigenous and traditional knowledge (ITK) into community-based EbA projects is positioned as critical to successful climate adaptation -The article provides empirical examples from Vanuatu and Samoa to demonstrate the different ways ITK relates to EbA projects. -There is widespread recognition that ITK is important for indigenous and local communities and can be employed successfully in EbA. *However*, this recognition is not being necessarily translated into ITK-informed or ITK-driven EbAprojects. - ITK should not be conceptualized simply as a collection of local environmental information that is integrated with Western scientific knowledge. Instead, ITK is part of nested knowledge systems (information–practices–worldviews) of indigenous peoples:

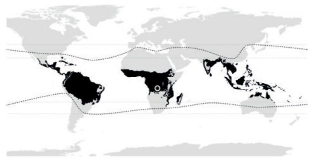
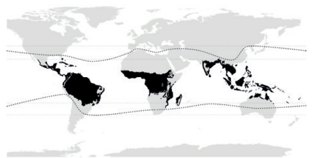
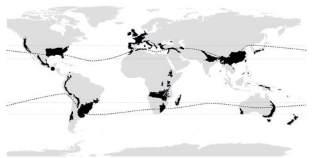
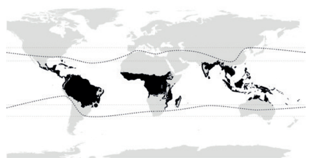
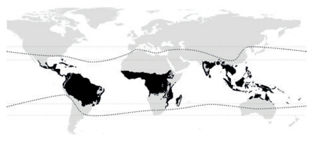
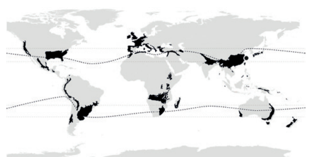
year	article	authors	highlights/interesting remarks
			local natural resource management, sociocultural governance structures, social norms, spiritual beliefs, and historical and contemporary experiences of colonial dispossession and marginalization. - There is a huge potential for researchers and ITK holders to coproduce knowledge that would be best placed to drive climate adaptation in a changing world.
2020	Climatic Design and Its Others. "Southern" Perspectives in the Age of the Anthropocene	Ferng, J., Chang, J. H., L'Hereux, E., & Ryan, D. J.	-The article employs southern architectural examples to interrogate normative assumptions around climatic design. The article seeks not only to challenge northern, temperate views but also to emphasize tropical zones as a significant paradigm for architects to consider. -Climate, capital and Power - (...) This homogenization of climatic design does a great disservice to the rich diversity of architectural ideas that lie between the equator and the southern tip of the earth.
2020	Can Nature Based Solutions contribute to water security in Bhopal? Climatic Design and Its Others. "Southern" Perspectives in the Age of the Antropocene	Everard, M., Ahmed, S., Gagnon, A. S., Kumar, P., Thomas, T., Sinha, S., Dixon, H., Sarkar, S.	*Keywords: catchment management, hydrogeology, water resources, ecosystem services, groundwater recharge, RAWES* -Soil impermeability hampers infiltration into the Bhojtal catchment (from which, as it is discussed in the paper, the long-term wellbeing of Bhopal city region depends). -Over-reliance on appropriation of water from increasingly remote sources is currently compensating for lack of attention to measures protecting or regenerating local resources that may provide greater resilience and regional self-sufficiency. -Improved knowledge of catchment hydrology on a highly localised scale could improve the targeting and efficiency of water harvesting and other management.
Ongoing project	Enhancing Adaptive Capacity to Climate Change through Conservation of Traditional Water Supply Sources (Wells & Bawdies) of Burjanpur City	Mr. Lokendra Thakkar	The project tackles the challenge of water scarcity in the city of xxx for the poor urban areas where water supply does not reach. The give approach is the follow: - Physical restoration of traditional water supply sources (wells, rainwater harvesting in buildings) - Restoration of water catchment by plantation, grassland development and soil moisture conservation strategies - Facilitation of community engagements for effective management of traditional systems
2020	Linking NbS with Water Management: A Case of South Megacities	Kumar, C. B., & Ghosh, S.	The paper (chapter of book), deploys the principles of nature-based solutions (NbS) in megacity environment -Delhi-, and argue there there exists possibilities and opportunities in NbS in the context of the global south as it offers cheaper, understandable, durable, climate-adaptive, resilient and equitable solutions.
2017	A framework for assessing and implementing the co-benefits of NBS in urban areas	Raymond, C. M., Frantzeskak, N., Kabisch, N.,	- The paper elaborates a valuable tool for guiding thinking and identifying the multiple values of NBS implementation. - They present a seven-stage process which can guide NBS implementation with a set of questions for consideration
2016	Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action	Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, McK., Artmann, M., Haase, D.,	- The paper elaborates a framework of indicators for the evaluation of NBS effectiveness according to: 1. *integrated environmental performance:* ecosystem regulation (decrease in air pollution, CO_2 overturn, % reduction in flood risk), biodiversity (increase in species numbers, functional richness and vegetation cover), regeneration derelict areas, ecosystem disservices (allergies) 2. *health and well.being:* physical and mental health, access, impact on quality of life 3. *citizen's involvement: involvement* in implementation, ownership and responsibility, community engagement 4. *transferability and monitoring:* integrated governance, long-term vialibility, city budget, transfer of actions -The paper clusters a series of potential barriers to NBS in order to overcome the ones that are a matter of perception, but also for finding opportunities to address them: 1. Fear of the unknown 2. Disconnection between short-term actions and long-term goals 3. Disconnection between short-term actions and long-term plans

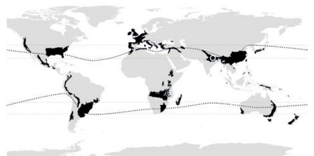
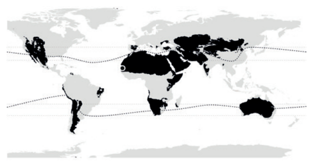
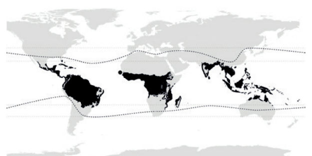
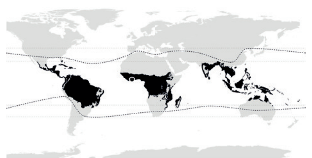
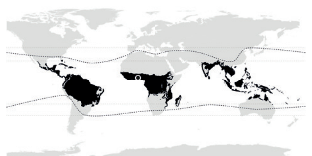
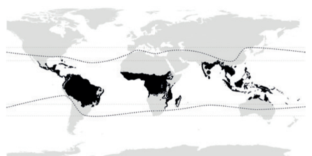
year	article	authors	highlights/interesting remarks
			4. Sectorial silos: departmentalization of fields of action and the impossibility of NBS to fit into one department 5. Paradigm of growth: the economic growth-oriented model hinders the implementation and boosting for green space projects - The paper identifies opportunities facilitating action for NBS: 1. Identification of Existing expert knowledge of policy makers, policy advisors, urban citizens, researchers, and urban planners about NBS in cities. 2. Establishment and utilization of collaborative governance approaches partnering different actors, responsibilities, 3. Learning from emerging partnerships of self-governance in cities
2010	Social Capital, Collective Action, and Adaptation to Climate Change	W.Niel Adger	The article reviews emerging perspectives on collective action and social capital ad argues that insights from these areas inform the nature of adaptive capacity and normative prescriptions of policies of adaptation. Case Studies are presented of present-day collective action for coping with extremes in weather in coastal areas in Southeast Asia and of community-based coastal management in the Caribbean. These cases demonstrate the importance of social capital framing both the public and private institutions of resource management that built resilience in the face of the risks of changes in climate.

Annex II
Case Study Long List

NBS for water-related challenges

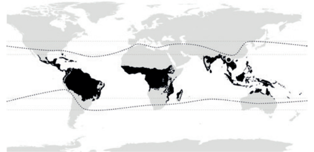
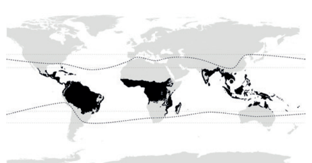
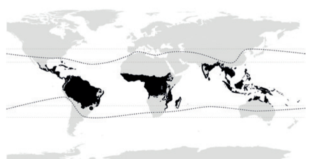
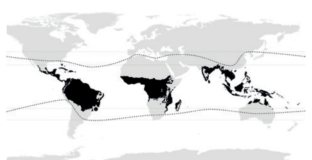
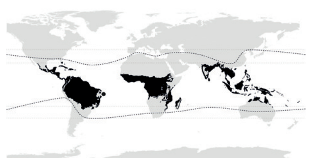
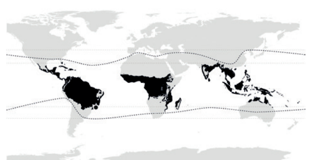
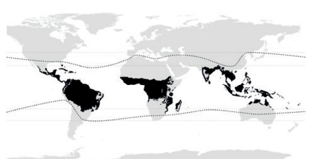
Case study long list - too much

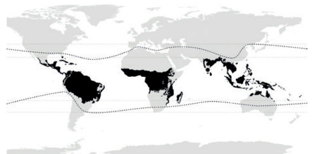
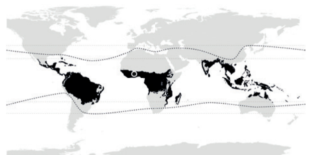
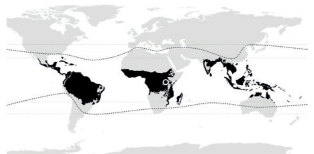
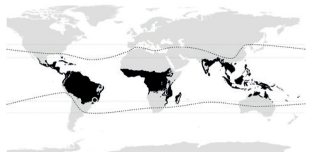
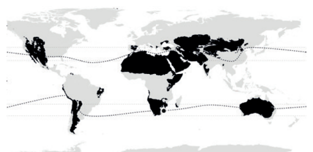
context outline the shaping of the risk						*NBS*		*phase*	*keywords*
geographical location (city, country climate, main biome)			land use setting (urban / peri-urban / rural)	addressed challenge (too much / too polluted / too little in riverine / coastal / delta / dryland)		type of NBS (I = physical intervention; C= community practice; P= policy guidelines / description: main aim and addressed ecosystem)	scale of implementation (urban-periurban approach / basin approach)	(ideation / in progress / completed & assessed)	
1		Kasangulu Republic of Congo Tropical climate	urban		too much Riverine	P "Catchment based approach to flood disaster risks and management" crystallizing in catchment protection measures at different levels.	basin approach	- completed	#Integrated Flood Management #Flood risk #Protection Measures
2		Bandar Lampung Indonesia Subtropical climate	urban		too much Coastal	I C Groundwater conservation through biopore infiltration holes. This technique is easily implemented by communities with low resources, reducing flood risk by accelerating soil infiltration capacity, recharging groundwater and reusing organic waste as compost and subsequent fertilizer.	urban approach	2014-2015 completed & assessed	#Community-Based Adaptation #Ecosystem Services #Biopore Infiltration holes
3		San Marcos Guatemala Tropical humid climate	rural		too much Riverine	P C With the support from the Tacan'a Project, communities are being empowered to create micro-watershed councils, lead watershed restoration and secure livelihoods. The main goal is to 'mainstream an ecosystem approach into catchment policies, planning and management' (WANI)	basin approach	2012-2017 (study) completed	#SGD6 & #SDG13 #watershed management #floods #land and forest degradation #agroforestry systems #Community-based Adaptation #Livelihoods
4		Arara slum Rio de Janeiro Brazil Tropical climate	favelas		too much Other	I Household implementation of green roofs within highly built-up and paved areas as a low-cost and low-maintenance solution to lower indoor temperatures, reduce urban heat-island effect and stormwater run-off while improving quality of life in slum communities.	urban approach household approach	2016 completed and assessed	#green roofs #slums #quality of life #low-income communities #urban heat-island #storm-water run-off
5		Khulna Bangladesh Tropical climate	urban, pero-urban and rural		too much Delta	P C I Comprehensive project proposal on the restoration of the tidal floodplains including interventions in different sections of the Delta and different scales -floodplain scale, regional scale, city scale-. The project addresses waterlogging and salinization, delta floods and land subsidence.	basin approach	2019 (project design) completed but not yet implemented	#Tidal River Management #Water as Leverage #Transcalar approach #Systems approach
6		Semarang Indonesia Tropical climate	peri-urban		too much Coastal	P C I The main aim is reducing coastal erosion and floods by means of mangrove restoration. The restoration of this lost ecosystem takes place through the community implementation of permeable, low-cost water structures that fixate sediment and reclaim new land.	peri urban approach	2015-2020 implemented & assessed	#Water as Leverage #Mangrove restoration #Coastal erosion #Land reclamation #Community-based Adaptation #Livelihoods #Land rights
7		Ningbo China Subropical climate	urban		too much Coastal	P I Aiming at restoring the capacity of this urbanized area to absorb, retain and reuse water (Sponge City Concept) as the main strategy to manage pluvial and coastal floods, the case of Ningbo includes a series of local-scale projects: slow flow areas, eco-corridors, hybrid drainages and constructed wetlands	urban approach	2016 implemented & assessed	#Sponge City Concept #Urban water management

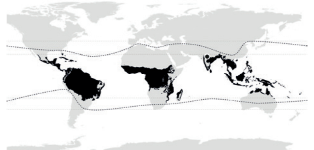
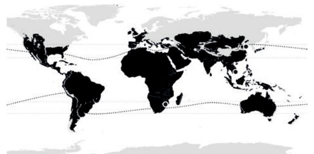
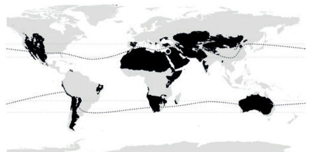
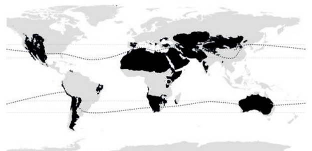
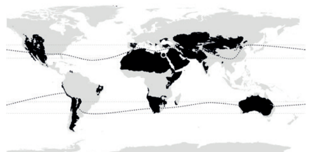
context outline *the shaping of the risk*				*NBS*		*phase*	*keywords*
	geographical location city, country climate, main biome	land use setting urban / peri-urban / rural	addressed challenge too much / too polluted / too little in riverine / coastal / delta / dryland	type of NBS I = physical intervention; C= community practice; P= policy guidelines / description: main aim and addressed ecosystem	scale of implementation urban-periurban approach / basin approach	ideation / in progress / completed & assessed	
8 	Gorakhpur India Subropical climate Wet forest	urban	 too much & too polluted Riverine	C I P Implementation of Peri-Urban Agriculture (PUA) concept to sustainable ensure peri-urban farmer livelihoods while protecting urban areas from riverine floods. Decentralized Solid Waste Management (DEWATS)	per-urban approach	2012-2016 completed & assessed	#Peri-Urban Agricultures #Community-Based Adaptation #Ecosystem Services #Livelihoods
9 	Nouakchott Mauritania Arid Climate	urban, peri-urban and rural	 too much Coastal	P I Urban coastal floods and erosion are being addressed in the Coastal Master Plan, incuding a zone development and protected areas, and the reinforcement of coastal dunes by fixating the sand using vegetation and planting of mangroves.	coastal approach	2018-2022 Coastal Master Plan	#Coastal erosion #Coastal floods #Coastal dunes reinforcement #Multi-sector investment plan
10 	Dakar Senegal Tropical Climate	urban, pero-urban and rural	 too much Coastal	P C Urban coastal floods and erosion are being addressed by integrated coastal zone plans providing coordinated action on coastal development including management of coastal erosion, flooding and pollution. The plan also includes citizen engagement to strenghthen resilience and improve livelohoods.	coastal approach	- Coastal zone Plan	#Coastal erosion #Coastal floods #Coastal zone plan #Citizen engagement #Livelihoods #Multi-sector investment plan
11 	Grand Lahou area Cote d'Ivoire Tropical Climate	urban, peri-urban and rural	 too much Coastal	P I Urban coastal floods and erosion are being addressed by a multi-sector investment plan (MSIP) aiming at the stabilization of lagoon's banks by reforestation and rehabilitation of mangroves	coastal approach	- Coastal zone Plan	#Coastal erosion #Coastal floods #Coastal zone plan #Mangrove restoration #Multi-sector investment plan
12 	Ouidah Benin Tropical Climate	urban, peri-urban and rural	 too much Coastal	P I C Urban coastal floods and erosion are being addressed by a multi-sector investment plan (MSIP) aiming at giving response to immediate actions and long-term coastal protection. With a landscape-base approach, the plan will conserve wetladns and mangroves, ensuring livelihoods.	coastal approach	- Coastal zone Plan	#Coastal erosion #Coastal floods #Multi-sector investment plan #Landscape-based approach #Mangrove conservation #Livelihoods
13 	Chennai India Tropical climate	peri-urban	 too much Coastal	P C I City of a 1,000 Tanks is the name of the project aiming at creating a network of water retention and supply ponds addressing water supply, sewage and flooding problems in the city.	urban approach	2015-2020 implemented & assessed	#Water as Leverage #Decentralized system of NBS #groundwater recharge #water retention

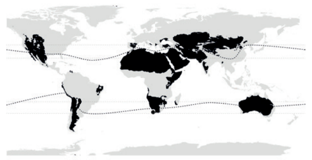
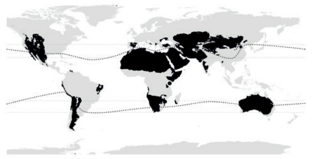
NBS for water-related challenges

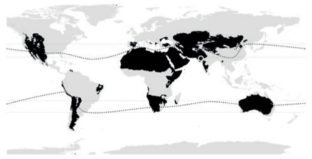
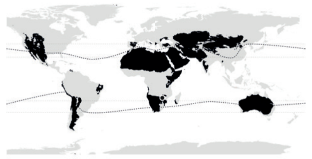
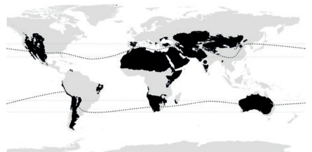
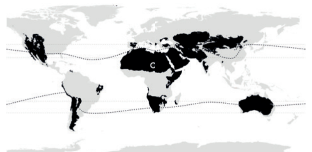
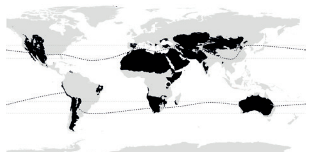
Case study long list - too much & too polluted

context outline the shaping of the risk						*NBS*			*phase*	*keywords*
		geographical location city, country climate, main biome	land use setting urban / peri-urban / rural		addressed challenge too much / too polluted / too little in riverine / coastal / delta / dryland	type of NBS I = physical intervention; C= community practice; P= policy guidelines / description: main aim and addressed ecosystem		scale of implementation urban-periurban approach / basin approach	ideation / in progress / completed & assessed	
14		Chiang Rai Thailand Subtropical climate	urban		too much & too polluted Riverine	I C	Community-led restoration of Nong Pung Urban River to provide aditional water storage, flood reduction and urban greening: revival of 2km dried-up section of the river, reclamation of water parks and food gardens, conversion of household-level agricultures into constructed wetlands for wastewater treatment.	urban approach	2012-2016 completed & assessed the community-led restored urban stream has transformed from a dump to a productive land	#Community-Based Adaptation #Ecosystem Services #Livelihoods
15		Can Tho Vietnam Subtropical climate	peri-urban		too much Riverine	I C	Community-led construction and co-management of riverbank biological erosion control: water hyacinth in the river, trees on bank. Also, with the widespread message "my riverbank, my responsability", a collective regulation for riverbank management is taking place since.	urban approach	2013-2016 completed & assessed after two flood seasons there has been no erosion damage	#Community-Based Adaptation #Ecosystem Services #Co-management #Co-monitoring #Co-funding
16		Sao Paulo Brazil Subropical climate	urban		too much & too polluted Other	I	The project proposes the re-naturalization of the urban Jaguare Creek including built wetlands -as retention and detention basins-, bioswales and rain gardens in order to: treat difuse pollution, mitigate urban heat-island, provide habitat for biodiversity and provide cultural and societal benefits	urban approach	2015-2017 (project design) completed but not yet implemented	#Interdisciplinar design #learning-by-doing #diffuse pollution #storm-water floods #creek renaturalization
17		Niteroi Brazil Tropical climate	urban		too much & too polluted Coastal	I	Lagoon restoration through water-sensitive design - phytoremediation in built wetlands- to address: management of solid waste, water pollution, protect and enhance biodiversity and incentivise ecotourism.	urban approach	2019 (executive project) completed but not yet implemented	#lagoon restoration #phytoremediation #diffuse pollution #multipurpose park #ecosystem services #flood management
18		Recife Brazil Tropical climate	urban		too much & too polluted Coastal	I	Urban park with designed wetlands along the river banks and filtration gardens to clean the water.	urban approach	2016 (executive project) completed but not yet implemented	#riverbank restoration #water quality #public urban open spaces #environmental education #regional economy
19		Rio de Janeiro Brazil Tropical climate	urban		too much & too polluted Coastal	P I	As part of the municipal plan to prevent urban sprawl and restore the Atlantic Forest of the city, the program identifies potential connectivity corridors and buffer zones. The project targets urban massive landslides and floods. Recreio green corridor project is the first implemented project since 2012	urban approach	2012 under implementation (delayed due to lack of political interest)	#urban landslides #coastal erosion and floods #urban sprawl #landscape ecology #green corridors
20		Dar-es-Salaam Tanzania Arid climate	urban and peri-urban		too much too polluted Coastal	P	Conservation of open spaces and green areas in urban and peri-urban areas in Dar es Salaam as the main strategy to tackle flood risks and groundwater exploitation	urban approach	2019 study	#Urban agriculture #Livelihoods #Urban greening

context outline *the shaping of the risk*					*NBS*		*phase*	*keywords*
	geographical location city, country climate, main biome	land use setting urban / peri-urban / rural	addressed challenge too much / too polluted / too little in riverine / coastal / delta / dryland		type of NBS I = physical intervention; C= community practice; P= policy guidelines / description: main aim and addressed ecosystem	scale of implementation urban-periurban approach / basin approach	ideation / in progress / completed & assessed	
21 	Ganjam India Tropical & subtropical climate	rural	 too polluted Dryland		I C	Training of women in India's water, sanitation and hygiene (WASH) stimulated family involvement in the building, operation and maintenance of toilets.	localized approach	- completed	#WASH #Gender empowerment #Community-Based Adaptation
22 	Asufiti North District Ghana -	rural	 too polluted Dryland		P I	Master plan including a 13-year initiative to promote universal access to safe water, basic sanitation and hygiene services framed within targets of SDG 6. The master plan provides a framework for coordinating and aligning efforts and drive community cohesion. Specific interventions are the drilling of new boreholes	basin approach	2018 - 2020 completed	#SDG6 #WASH #Masterplan
23 	Kampala Uganda	urban	 too polluted -		C I	The research focuses on Integrated approaches and strategies to address the sanitation crisis in unsewered slum areas in african mega-cities with a demonstration site in the Bwaise III slum in Kampala.	per-urban approach	2008-2012 (study) completed	#SGD7 #low cost technologies #natural treatment system #Decentralized Sanitation and Reuse (DeSaR) #Ecological Sanitation (EcoSan)
24 	Petropolis Brazil Tropical climate	rural	 too polluted Other		I C	As a strategy for waste-water treatment in difficult access areas in high and steep hills where low-income population live in unplanned dwellings, the project proposes a biological wastewater treatment with biodigestor and wetlands. The project includes environmental education programs for local residents.	rural approach	2002 completed and assessed	#mountainous region #waste-water treatment #environmental education
25 	Durban-Pietermaritzburg South Africa Arid climate	urban	 too polluted Riverine		P	In order to address water security in Mungeni catchment that feeds the main cities in the country, a trans-scalar and cross-sectorial partnership is created to enable policy environment for investment and rehabiliattion of ecological infrastructure in the catchment.	basin approach	-	#Partnership #Water pollution #Catchment rehabilitation

context outline the shaping of the risk					*NBS*		*phase*	*keywords*
	geographical location (city, country, climate, main biome)	land use setting (urban / peri-urban / rural)	addressed challenge (too much / too polluted / too little in riverine / coastal / delta / dryland)		type of NBS (I = physical intervention; C= community practice; P= policy guidelines / description: main aim and addressed ecosystem)	scale of implementation (urban-periurban approach / basin approach)	(ideation / in progress / completed & assessed)	
26 	Indore India Subtropical climate -	urban		too little & too polluted Dryland	I Urban and peri-urban lake restoration in order to ensure local water resources during emergencies and revive socio-economic and environmental functions: source of water supply, micro-agriculture, micro-climate, groundwater recharge. C Conjunctive Water Management to address water supply issues: community managed RO plant, individual and community water tank storage, rainwater harvesting and recharging	urban approach	2014 - 2018 completed & assessed After successful restoration of two lakes, a floating island in the middle of the lake is being used for water purification	#Water pollution #Lake restoration #Water purification #Community-Based Adaptation #Livelihoods
27 	Peri-urban Great Maputo, Mozambique Tra Vinh Province, Vietnam Laizhou Bay, China	peri-urban		too little & too polluted Coastal	I C The sudy researches collaborative and Nature-Based measures to mitigate groundwater salinity to improve water security in coastal areas under socio-economic and climate change. Among the explored measures: alternative land uses -salt-tolerant crops-, optimized pumping practices and well locations, participatory monitoring and management of aquifer recharge.	urban approach	study	#Water and food security #Groundwater exploitation #Polluted coastal aquifers #Saltwater intrusion #Salt-tolerant crops #Aquifer recharge
28 	Zarqa River Basin Jordan	rural		too little & too polluted Riverine	P C The project aims at reviving traditional *hima* land management -consisting of setting land aside to allow for the land to naturally regenerate itself- in order to reduce stress on groundwater resources both from a quality and quantity perspective. Along with it comes the empowerment of local communities by transferring management rights to them.	basin approach	2014 completed & assessed Results are showing an increase in economic growth and conservation of natural resources within the basin	#*hima* land management #Groundwater depletion #Capacity-building #Economic growth
29 	Lake Naivasha Kenya	rural		too little & too polluted Riverine	P C I A series of land management practices have been implemented at a basin scale in order to improve downstream water quality and quantity: rehabilitation of riparian zones, agroforestry farming and grass terraces to reduce erosion. The use of a water-centred PES scheme has gathered partners throughout the basin delivering tangible livelihood benefits, economic benefits, biodiversity.	basin approach	2010 completed	#Water availability #Water-centred PES scheme #Livelihoods #Land management
30 	Bilbeis Egypt	peri-urban		too little & too polluted Dryland	I Constructed wetlands as a nature-based cost-effective infrastructure for wastewater treatment. Being used as a secondary-level treated wastewater effluent, the project has contributed to water conservation and preservation of groundwater resources	peri-urban approach	- completed	#Constructed wetlands #Wastewater treatment #Water conservation #Preservation groundwater

context outline *the shaping of the risk*						*NBS*		*phase*	*keywords*
geographical location city, country climate, main biome			land use setting urban / peri-urban / rural	addressed challenge too much / too polluted / too little in riverine / coastal / delta / dryland		type of NBS I = physical intervention; C= community practice; P= policy guidelines / description: main aim and addressed ecosystem	scale of implementation urban-periurban approach / basin approach	ideation / in progress / completed & assessed	
31		Cape Town South Africa Arid Climate	urban, peri-urban and rural		too little & too polluted Other	P C I Aiming at tackling water scarcity and urban water supply problems downstream, the project restores water provision through forest management initiatives upstream removing invasive species.	basin approach	- completed and assessed	#Water fund #Watershed job creation #Watershed reforestation
32		Tana-Nairobi Kenya Arid Climate	urban, peri-urban and rural		too little & too polluted Other	P C I Aiming at addressing water provision and quality affected by sedimentation throughout the watershed, the Water Fund supports upstream water and soil conservation measures.	basin approach	- completed and assessed	#Water fund #Watershed job creation #Watershed reforestation

context outline *the shaping of the risk*					*NBS*		*phase*	*keywords*
geographical location city, country climate, main biome		land use setting urban / peri-urban / rural	addressed challenge too much / too polluted / too little in riverine / coastal / delta / dryland		type of NBS I = physical intervention; C= community practice; P= policy guidelines / description: main aim and addressed ecosystem	scale of implementation urban-periurban approach / basin approach	ideation / in progress / completed & assessed	
33 	Rajastan India	rural		too little Dryland	(I) Supporting local communities to undertake landscape scale restoration through small scale water harvesting structures and regeneration of forests and soils to recharge groundwater resources and combat droughts.	basin approach	- completed & assessed Everard (2015), undertook science-base assessment confirming an array of socio-economic benefits in rural India	#Water security #Landscape restoration #Gender empowerment #Community-based Adaptation #Livelihoods
34 	Shashe, Tuli and Sashne Rivers Zimbabwe	rural		too little Dryland	(I) Construction of 'sand dams' -walls across the river in the sand- to increase the volume of water stored in the alluvial aquifer and its accesibility. The solution enables farmers with agricultural opportunities throughout the year, enancing income and livelihoods. The project needs to be supported by a community monitoring device to ensure the sustainable a management	basin approach	- completed	#Nature-based water storage #Dry Rivers #Alluvial aquifer #Shallow groundwater reservoirs #Sand dams #Livelihoods #Moisture deficits
35 	Burhanpur India Subropical climate	peri/urban and rural		too little Dryland	(P) (I) Addresing recurring droughts and water availability through participatory groundwater management and conservation of traditional water supply systems: wells and bawdies, Kundi Bhandara Network and rainwater harvesting.	peri-urban approach	- in process	#Participatory Groundwater management #Restoration of traditional systems #Kundi Bhandara Network
36 	Great Green Wall Sahel Arid climate	peri/urban and rural		too little Dryland	(P) (I) A transnational initiative aiming at restoring 100 million hectares of land to stop the advance of the Sahara Desert providing food security, ensuring livelihoods, jobs and sequestering carbon.	peri-urban approach	- in process	#Great Green Wall initiative #transnational collaboration #food security #desertification #Livelihoods
37 	Mau Forest Complex Kenya Arid Climate	rural		too little Dryland	(P) (C) (I) National recognition and support of indigenous communities and livelihoods as upstream managers of the forest. Enhancing their knowledge to optimise the use of natural resources in a sustained manner.	basin approach	2018- in progress	#Indigenous Traditional Ecological Knowledge (ITEK) #Holistic landscape-scale approach

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