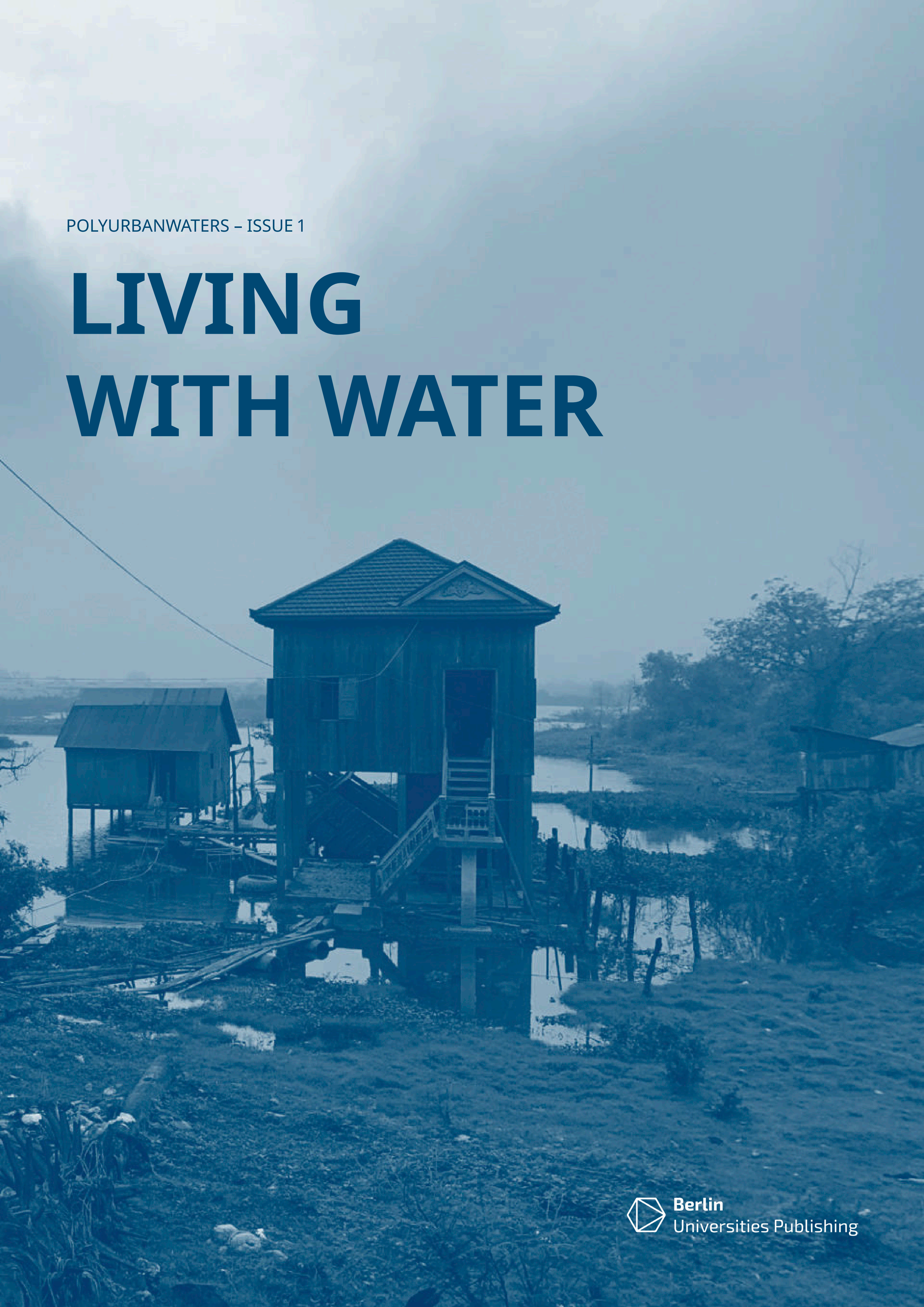
POLYURBANWATERS – ISSUE 1

LIVING WITH WATER



Berlin Universities Publishing

Anke Hagemann | Frederic Hebbeker | Adrian Hodgson | Xhesika Hoxha | Elise Phuong Ha Nguyen | Lars Ribbe | Ania Wilk-Pham (Eds.)

Living with water

The scientific series by PolyUrbanWaters (PUW) is edited by:

Series editors (in alphabetical order):
Dr. Bernd Gutterer, Prof. Dr. Anke Hagemann, Prof. Dr. Lars Ribbe

Issue editors (in alphabetical order):
Anke Hagemann, Adrian Hodgson, Frederic Hebbeker, Xhesika Hoxha, Elise Nguyen, Lars Ribbe, Ania Wilk–Pham

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By combining scientific and essayistic writings, photographic works, and/or ethnographic studies including interviews, spatial mappings and drawings, the PolyUrbanWaters periodical will seek to bridge academic, practice and policy discourses around global sustainability challenges at the interface of polycentric water management and the Water-Sensitive urban develpment.

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PolyUrbanWaters field trip, Kratié, Cambodia, 2019

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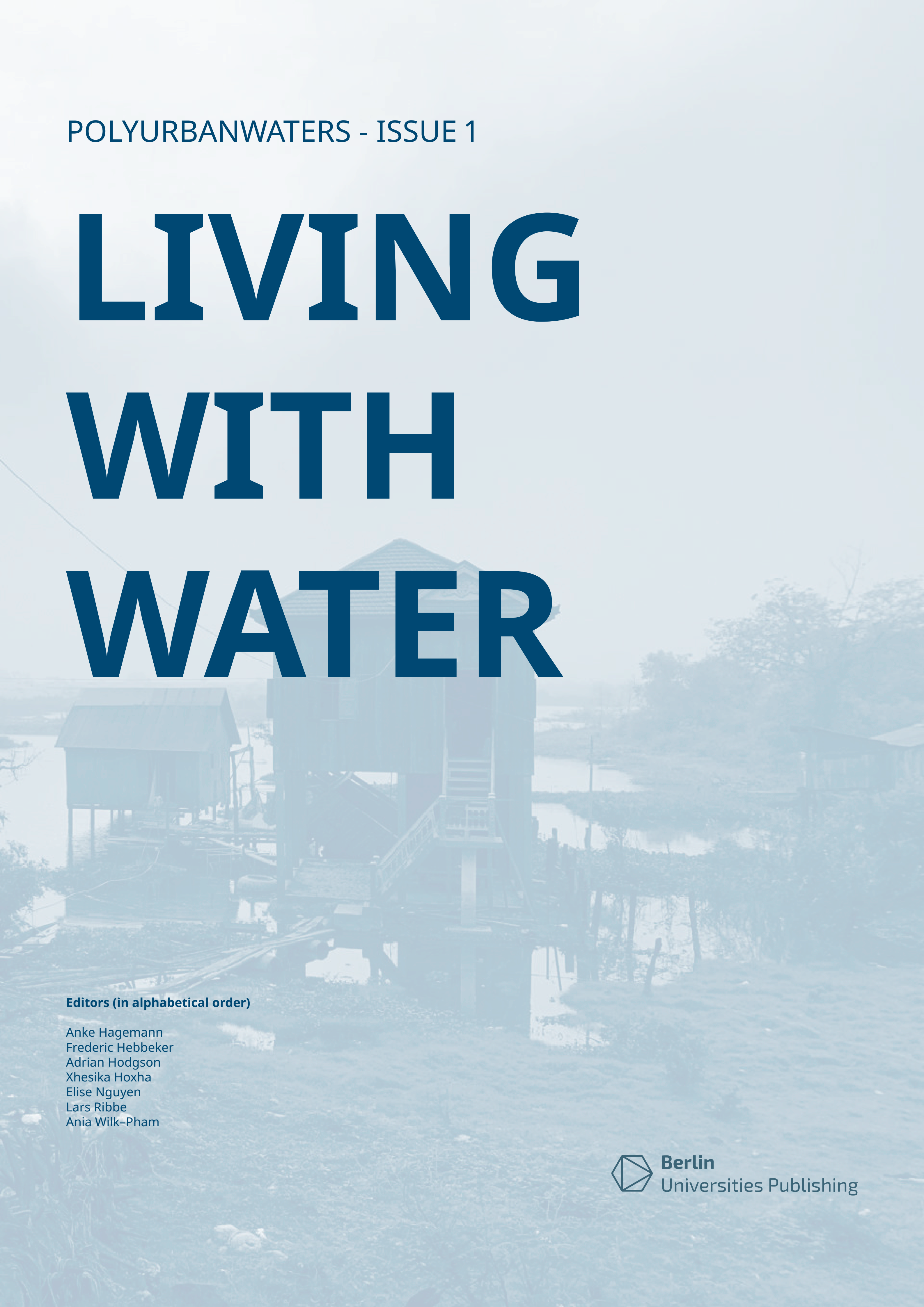

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ORCID iD Anke Hagemann:
https://orcid.org/0000-0002-9586-6266

ORCID iD Frederic Hebbeker:
https://orcid.org/0009-0006-3472-3866

ORCID iD Xhesika Hoxha:
https://orcid.org/0000-0002-2331-143X

ORCID iD Adrian Hodgson:
https://orcid.org/0009-0009-4905-4054

ORCID iD Elise Nguyen:
https://orcid.org/0009-0009-1025-9423

ORCID iD Lars Ribbe:
https://orcid.org/0000-0003-3052-1782

ORCID iD Ania Wilk-Pham:
https://orcid.org/0009-0009-4380-7991

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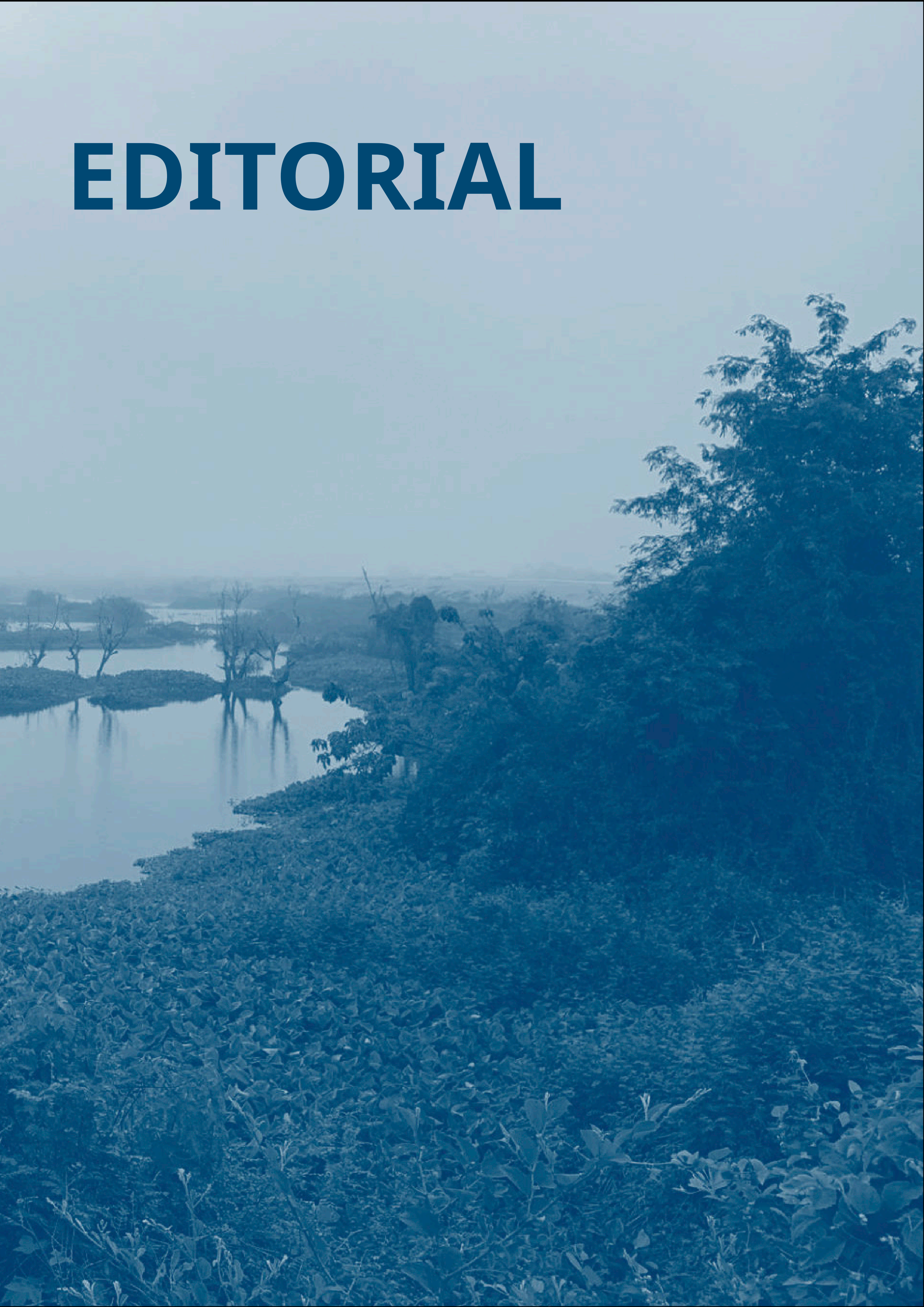
Source: PUW field trip, Kratié, Cambodia, 2019

EDITORIAL



Adrian Hodgson, Frederic Hebbeker, Xhesika Hoxha, Elise Nguyen, Ania Wilk-Pham

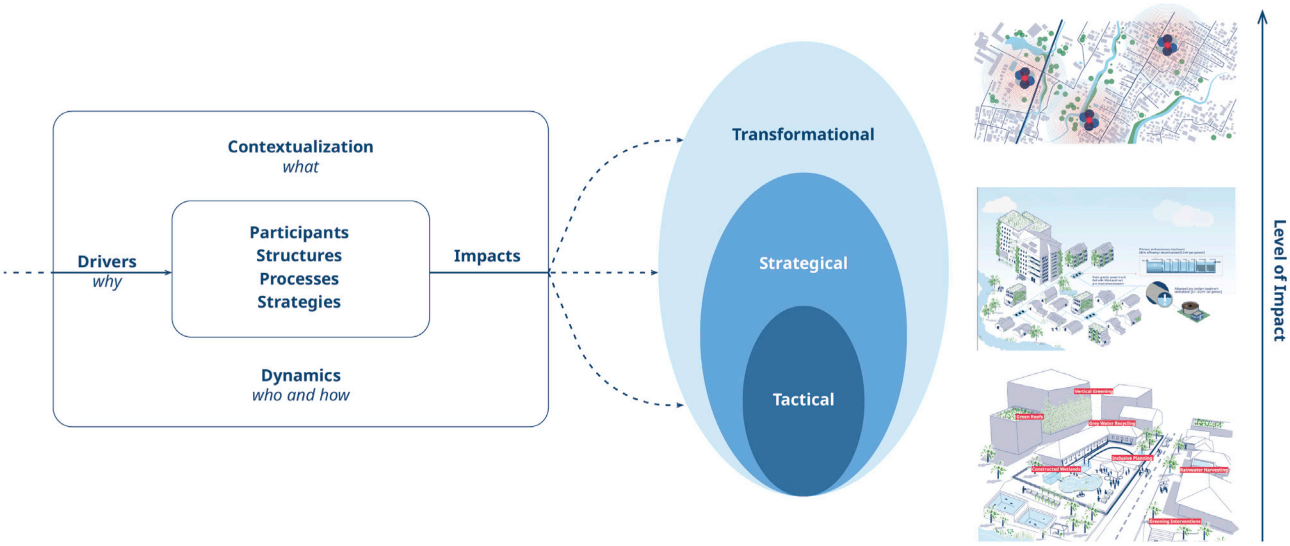
Editorial Remarks

Water is life – however, in today's cities, the health and social well–being of citizens are strongly influenced not only by the quality and quantity of water available to them and the environment, but also how water is perceived, utilised and managed. The dual pressures of climate change and (rapid) population growth are new realities for cities throughout the world. The limitations of classical models of urban planning and urban water management are being increasingly observed in forms of intractable land use challenges (uncontrolled, illegal expansion and urban sprawl), together with growing demands on water sources, water pollution, extreme climate events and altering precipitation patterns.[1] Combined, these pressures exert stress on ecosystems that traditionally served to buffer natural resources. Now, more than ever, cities urgently need to equip themselves with ample political and citizen willingness, know–how, capacities, and resources (natural, human, capital) to proactively and confidently face the considerable uncertainties ahead.[2] Given that urban space, natural resources, and materials are already often very limited in metropolitan areas, a mantra of doing more with less has become vital – essentially this translates to smarter and more efficient systems and behaviours in use/consumption, reuse, and renewal of natural resources, and in particular water (ibid.). In further reflecting on how water affects and enhances our lives, it is vital to understand the role that social values and perspectives have in guiding urban planning and design decisions, and urban water management practices, so that our cities can be more resilient when confronting an uncertain future.

On a methodological level, a deep appreciation of the context's environmental and socio–economic dynamics and impacts is vital for planning a feasible pathway of transition to the commonly desired future. Figure 1 below visualises different levels of action needed to simulate such a transition and includes: individual projects (the tactical level), overarching objectives (the strategic level) and general approaches (the transformational level).

In terms of planning activities, it is vital to include multiple scales of assessment and to integrate and interconnect local environmental and infrastructure networks. This eventually contributes to the adaptation to the aforementioned challenges and often includes basin wide water management and closer collaboration across various departments on local, provincial and national levels.[3]

Figure 1: Assessment levels for effective transition (after Chesterfield et al., 2021)



Transdisciplinary Research

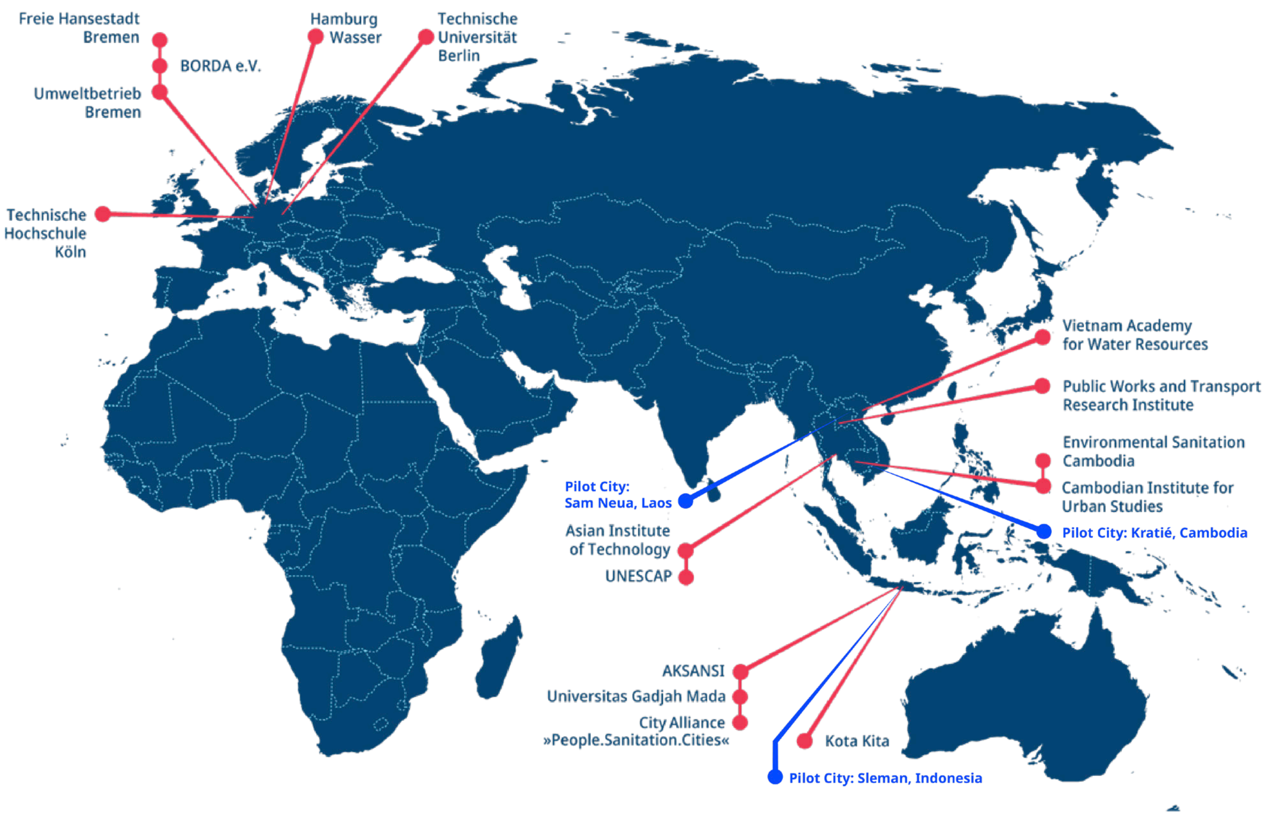
Against this backdrop, contemporary pro–active and inclusive approaches in urban water management and urban planning are being put to the test in cities through-out the world following intensive rethink-ing, application, lessons learned and grad-ual paradigm shifts. The more prominent, leading models over the last decades, such as "Water-Sensitive cities" and "water–wise cities" are essentially striving for water–relevant urban transformations that help cities to become more resilient, livable, productive, and sustainable.[4] Here multi-ple approaches, instruments and experi-ences are already available (for example, as shown in Figure 4). Global examples of these are captured within this issue of the PolyUrbanWaters Periodical.

In these models, urban water is a cross–cutting issue in urban development where participatory, people–centreed approaches are applied that sufficiently engage a full spectrum of sectors and stakeholders in collaborative planning processes (Articles 2, 5 and 7); progress occurs incrementally and strategically over time; planning pro-cesses are flexible and adaptable/tailorable to a context's specific fundamental realities and development dynamics; solutions are environmentally and financially sustainable and function in an integrated format, while being realistic to implement and can be sustained over the long term.

These principles are manifested within the PolyUrbanWaters Project and its polycentric approach for urban water management, which specifically responds to the needs of secondary and tertiary cities of Southeast Asia. In this region, approaches, principles and tools such as those mentioned above are either still at an elementary and forma-tive stage, or do not exist at all.[5]

As such, in its core purpose, the PolyUrban-Waters Project performs practice–oriented, transdisciplinary research to provide sec-ondary and tertiary cities in Southeast Asia with viable tools and approaches to proac-tively shape their processes of transforma-tion towards Water-Sensitive urban design. Here, cities, academic institutions and civil society organisations from Cambodia, Ger-many, Indonesia, Laos, Thailand and Vi-etnam (as shown in Figure 2), collaborate to develop such tools and approaches. In doing so, the project in turn contributes to the localisation of the Sustainable Devel-

Figure 2:
Project partners and pilot cities.
Source: PolyUrbanWaters



opment Goals (SDGs) and the New Urban Agenda (NUA).

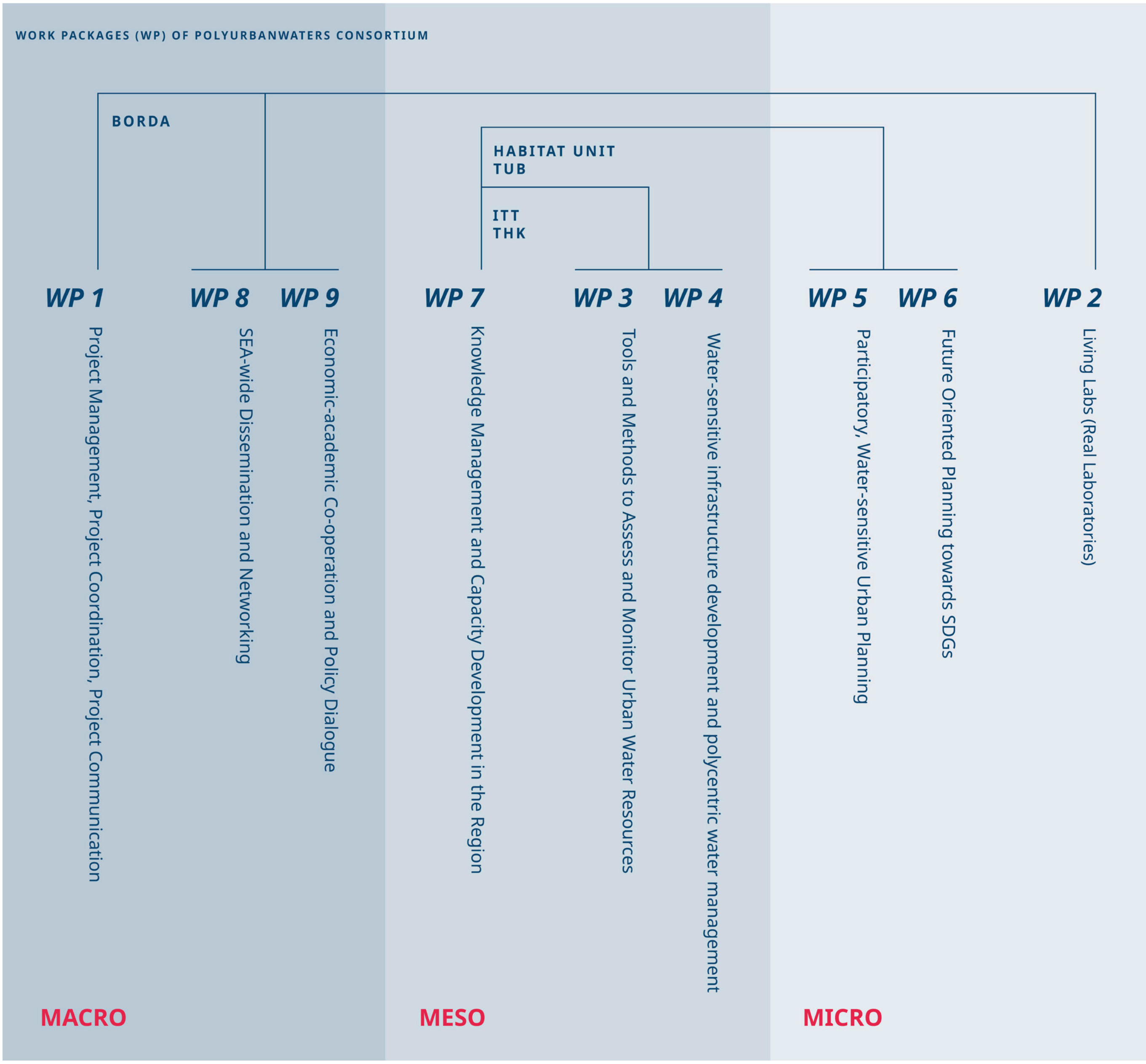
Based on the hypothesis that polycentric approaches to urban water management can address mismatches between needs and capacities of these cities, the research project pursues the following questions utilising the work packagess shown below in Figure 3:

1. How can a diverse set of stakeholders contribute to building an inter– and transdisciplinary local knowledge base on water and urban development, related to challenges in the SEA region? How can this knowledge be scaled and regularly updated to serve as a basis for inclusive and future–oriented municipal planning approaches across the region?

2. How can effective and sustainable Water-Sensitive urban development be fostered through a combination of centralised and decentralised technical and social–ecological innovations, including monitoring techniques, Nature-based Solutions (NbS), participatory strategic planning and effective water management structures.

3. How can "water" serve as a strategic entry point towards integrated, inclusive and resilient urban development that is guided by the SDG framework? Which polycentric, intersectoral and participatory governance ap-

Figure 3:
Work packages of PolyUrban-Waters Consortium
Source: PolyUrbanWaters



proaches are required to plan, develop, sustainably operate, and finance such integrated Water-Sensitive development that has the capacity to evolve further in line with dynamic urbanisation processes?

4. How can local innovation processes inform new practice–oriented pedagogies, capacity building approaches and research agendas to strengthen a network of academic institutions in the region?

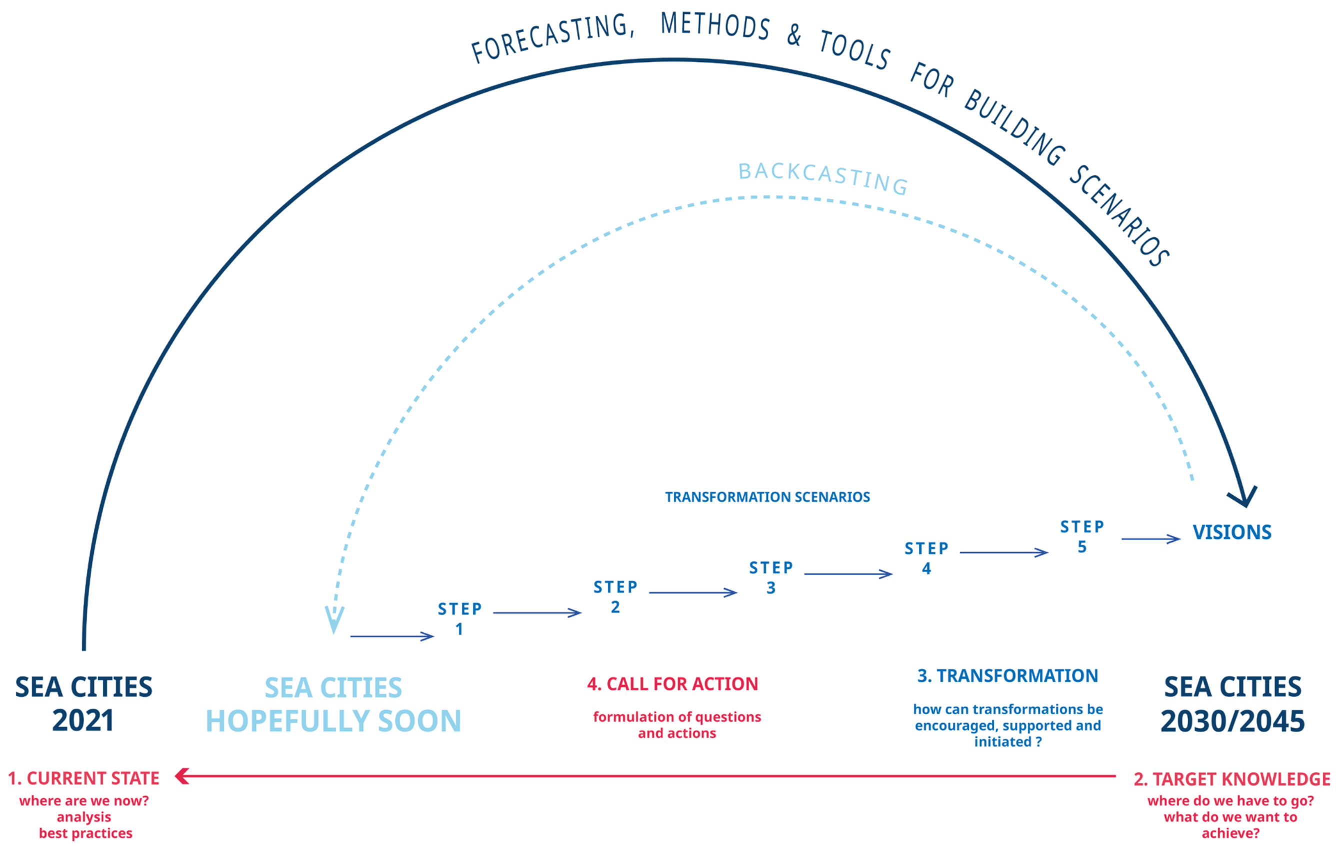
Living with Water

Living with water is the first issue of the PolyUrbanWaters Periodical. It accompanies the the research project activities by exploring emerging topics at the interface of urban planning and urban water management as well as various key sectors. The case studies introduce a contemporary perspective on inclusive approaches in urban water management and urban planning. Articles presented in the Living with Water issue are based on the experience of cities from around the world and combine an important link between theoretical framework and practice on the ground.
The articles are divided into two parts: firstly, theoretical and local contextualisation, followed by a selection of case studies and applied methods. The first part introduces applied assessments and experiences from the local context with three articles from urban villages or neighbourhoods in Indonesia. The second part explores contemporary tools and methods for a qualitative and geospatial assessment of urban water management and planning in six articles from different experiences around the world.

A. Theoretical and local contextualisation

The opening article focusses on the topic of Water Knowledge and the importance of understating, definition, and perception of urban water resources. With the topic of Water Resilient Urban Design and Planning, the second article explores planning tools that use water as a catalyst for sustainable transformation processes, and their contribution towards the localisation of global sustainability goals with an example of Sariharjo, a neighbourhood in Sleman, Indonesia. The third article presents the topic of Water Ceremony in Petung and Brayut Villages in Sleman, Indonesia, with analysis of urban expansion and ways in which communities perform cultural rituals to improve ecosystem services.

Figure 4:
Stages of Vision Building Process
Source: PolyUrbanWaters



B. Case studies of applied methods

Contemporary tools and methods for urban water management and planning are investigated in the following five articles, beginning with a conceptualisation and application of an evaluation framework for a Rapid Assessment of Nature-based Solutions (NbS) for Water Management. It is presented in the context of urban and peri–urban environments in Southeast Asia. Following on, Article 5 presents the Challenges and Future Perspectives of Water–Wise Urban and Neighbourhood Development, lessons learned from the RISA Structure Plan 2030 (RISA 2015) and relevant concepts and solutions for a sustainable stormwater management in Hamburg, Germany. In Article 6, Implementing Water-Sensitive Urban Design and Green Infrastructures in the Peruvian Context, the research team from the LIWA Project explains the Lima Ecological Infrastructure Strategy (LEIS) looks at urban–rural linkages within the city, with the application of ancient strategies to urbanise green recreative and productive landscapes while protecting food–security in Lima's peri–urban areas. In Article 7, neighbourhood–based participatory processes applied in the project "BREsilient – climate resilient future city Bremen" are introduced where, in the face of an increasing threat of heavy rainfall, floods and storm surges due to climate change, design adaptation and precautionary measures, especially for unprotected areas are being sought. The concluding two–part article introduces the case study Kratié in Cambodia with remote sensing approaches to flood inundation mapping, which can yield results important for planning of future urban development.

Conclusion

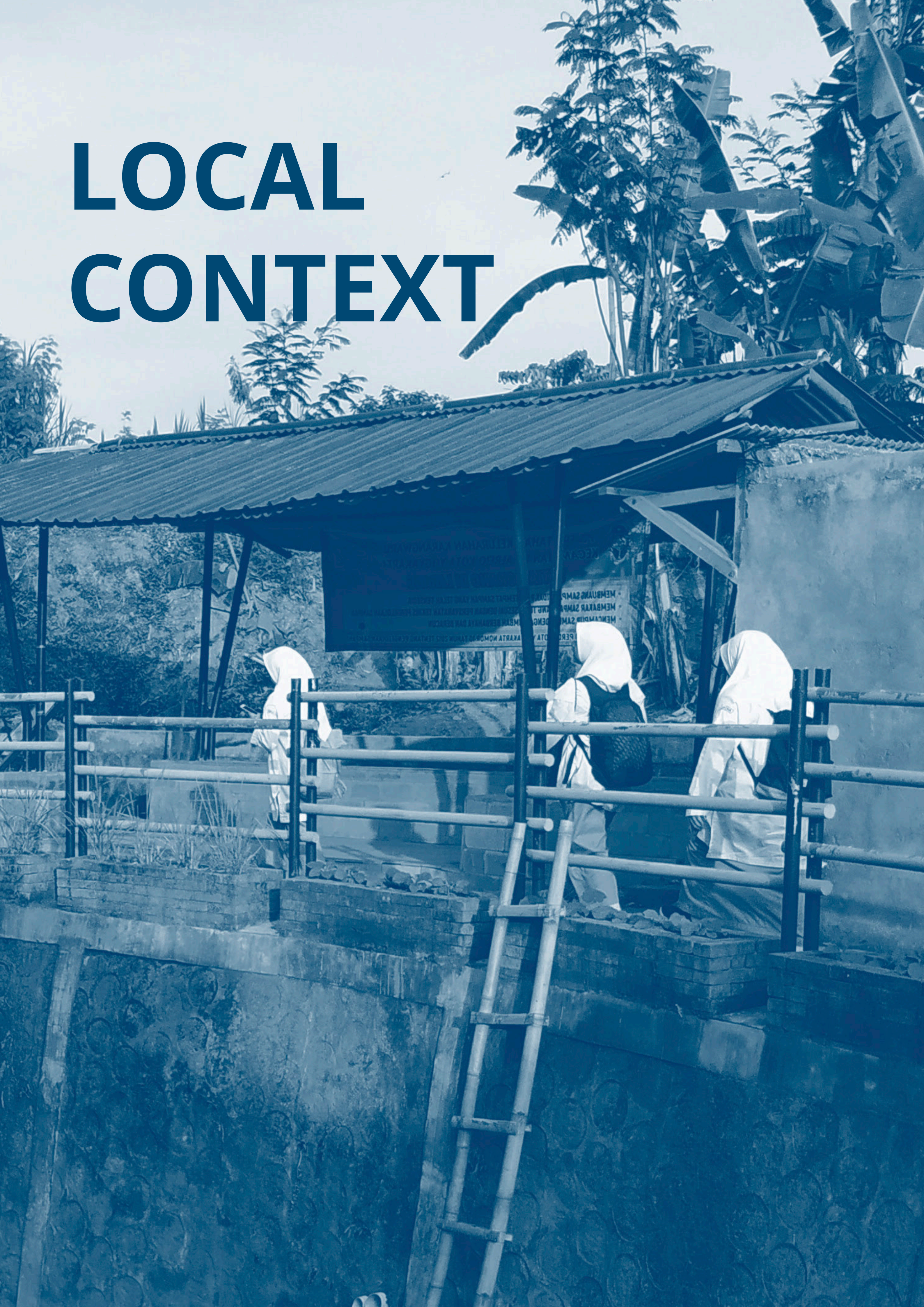
If "*water is life*", and the challenges surrounding water in and around cities continue to grow, then exploring how new, adaptive and context responsive approaches can help cities is now critical for their future development, liveability and quality of life. Approaches and case studies presented in this periodical represent contemporary experiences of cities which are exploring ways to "do more with less" to systematically plan urban development and manage urban waters in an inclusive and pro–active manner. Moreover, these approaches attempt to understand multifaceted list of local needs and adapt to them in order to engender efficient systems and behaviours in consumption, reuse, and renewal of water resources. A fundamental understanding and appreciation has been established that urban water is a cross–sectoral issue in urban development and that the benefits of participatory, people–centred and transdisciplinary approaches are increasingly being recognised and implemented as essential tools for achieving sustainable, effective long–term impacts across all sectors. Given the common list of pressing challenges facing secondary and tertiary cities in Southeast Asia and globally, practice–oriented research and extensive sharing of lessons learned is considered an essential step in developing pathways for liveable, Water-Sensitive urban futures.

"Urban water is a cross–cutting issue in urban development where participatory, people–centred approaches are applied that sufficiently engage a full spectrum of sectors and stakeholders in collaborative planning processes."

1 *Dickhaut et al., 2022*
2 *IWA, 2016*
3 *Chesterfield et al., 2021*
4 *CRCWSC, 2021; IWA, 2016*
5 *Dekker G. et al., 2020*


Source: PUW field trip, Sleman, Indonesia, 2022

LOCAL CONTEXT



Xhesika Hoxha, Ania Wilk–Pham, Hasanatun Nisa Thamrin

Water Knowledge

Understanding the perception of various stakeholder groups and their impact on the sustainable management of urban waters in Sariharjo village in Indonesia

Case study of Sariharjo Village, Indonesia

The current water situation in South-east Asia is very concerning, the region's water resources are experiencing multiple burdens (i.e. scarcity, flooding, water pollution), and different approaches are being sought to enable a change from conventional water management systems that have limited sustainability to be replaced with new solutions that will ensure long–term sustainability.[1] It has been proven that a considerable contributing factor to unsustainable water management and use is often a lack of understanding of water resources and systems[2] and that water literacy has a growing importance for improving water sustainability, especially in developing countries.[3] Such research demonstrates that water sustainability must be founded on clear knowledge and understanding of local water resources and their relationships with humans and global systems. We believe that an active and conscious engagement through the creation of water knowledge understanding is critical for achieving long–term water sustainability in the region and providing education is one of the ways to trigger participation.

In this article, we will focus on potential methodologies for analysis of current water knowledge status in the region based on a case study of Sariharjo Village in Sleman Regency, Indonesia, where preliminary analysis was done and lessons learned can be driven from. The aim is to identify water related–knowledge of the local governments and communities on the village level about the influence of household (their daily) activities on urban water sources, urban water cycle, water quality, river catchments, stormwater, and planning and management instruments and develop a new perspective on the major challenges and opportunities that may lie ahead

Water resources are crucial for the development of urban and rural areas and Sariharjo village is facing major challenges with regard to water resources such as the convention of agricultural land to build up areas, water pollution (e.g. E.coli, iron, mercury, etc.), loss of riparian zones along the river, drought in the dry season and floods in the wet season.[4] Indonesia's water management involves various actors and institutions at different levels of government starting from the national to local level.[5] The management of water resources has largely shifted from the "top government" to "bottom governance", with implications for the sectoral and intersectoral actors involved in water resources, creating a significant gap and ambiguity as to who has the authority to manage water resources.

Ensuring future sustainable water resources management requires the engagement of the community to accept approaches to water management of changes in policy, practice and technology. Water–wise citizens are able to understand the risks (flooding, water pollution, scarcity) and opportunities (human well–being, recreation, tourism, intellectual development, spiritual enrichment, reflection and creative and aesthetic experiences) that can be created by water resources.[6] It is It is signficantly important that water–wise citizens are involved in planning and managing sustainable urban water vision, particularly in developing countries – engaged, water–wise citizens are more open to adopting their behaviours and developing acceptance for solutions that can improve water services.

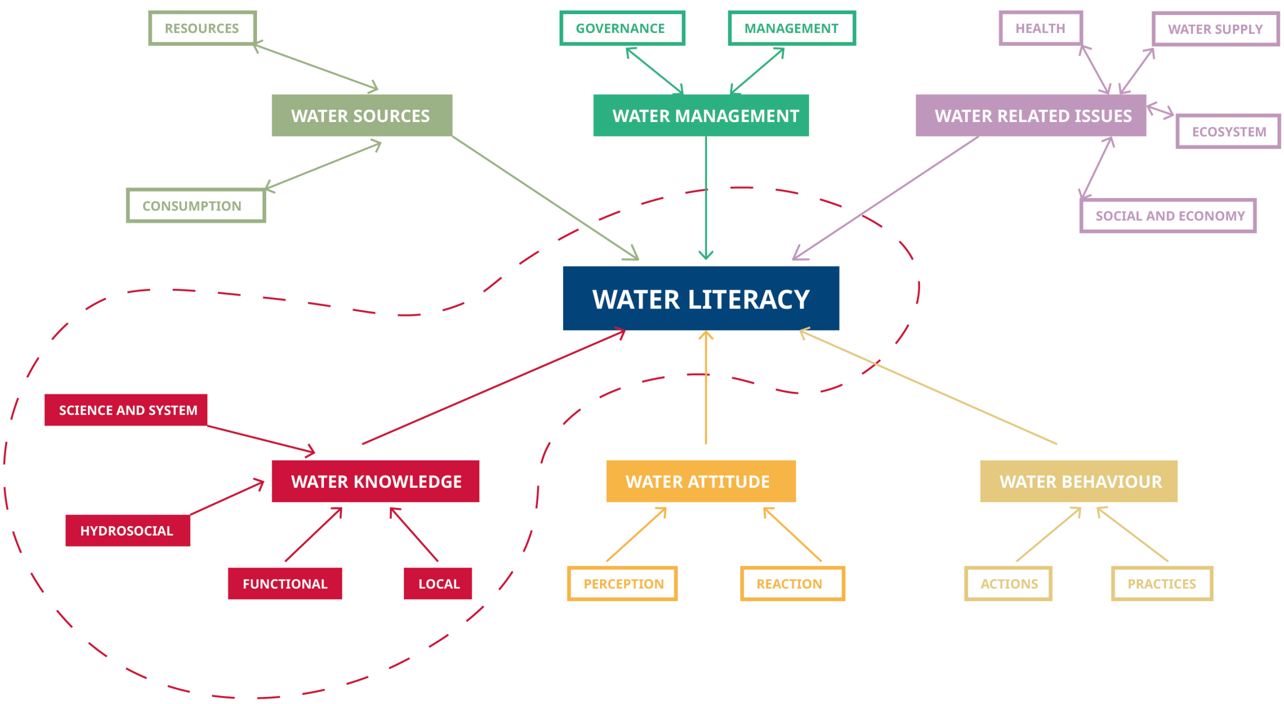
Some of the determinants of water–related knowledge are educational achievement and the factors that facilitate educational achievement. Also, diverse life experiences and personal interests contribute to associative learning, socio–economic status, personal interest, geographic experiences, such as region of residence and experience of drought, or particular rainfall patterns, household contexts, such as home ownership or the presence of gardens, social experience such as participation in community groups, use of waterways or life satisfaction, and exposure to information.[7] Other social factors that influence water knowledge are poorer reading skills, being an immigrant, or speaking a language other than the primary language. Previous research have noticed that there is a lack in examining the role of other types of life–experience in contributing to water–related knowledge such as negative life experience, emotional stressors or poor life satisfaction, participation in community groups may create opportunities for informal learning.[8]

Water Literacy and Water Knowledge

Water literacy means having basic knowledge of water resources and other aspects that are interconnected with it, and being water literate means having a basic understanding of how to use or manage the water sustainably as a manifest of understanding the importance and significance of the role of water in life and the relation between water cycle and social system.[9] According to Maniam etal., the definition of Water Literacy includes a combination of critical and active understanding of water sources, water management, and water security issues, which overall encompasses water knowledge, attitude, and behaviour.

For the purpose of this study, we particularly focus on Water Knowledge, which is one of the components of Water Literacy (Fig. 1). Water knowledge is multiplicitous, emerging from not just western science but also historical and a geographical process, cultural traditions, and spiritual knowledge.[10] According to McCarroll and Hamann[11], within Water Knowledge, we can distinguish different types of knowledge. For the analysis, we distinguish four main components of Water Knowledge:

Figure 1: The elements of Water Literacy (adapted from Maniam et al., 2021)



A. Science and System Knowledge which encompasses water's unique scientific properties and its significance for living systems. This includes the water cycle and water's ability to transport dissolved and solid materials, ecosystem needs and flows.

B. Hydrosocial knowledge refers to the bi–directional and continuous interactions between society and water resources. It focusses on how human actions impact water quality and health of water resources, and at the same time, how the health and quality of water resources directly impact human health and welfare. Hydrological science underpins most decision–making on water resources and is the basis for assessing risks related to water such as floods and droughts. But despite its critical societal relevance, this area of science is characterised by an acute scarcity of data in both the spatial and temporal domains[12], which contrasts significantly with the heterogeneity and complexity of actual water management and governing processes.
In recent years, the link between water and society has risen to the top of scientific and public discourse. Recognition, reflection, and representation of water's larger social elements are necessary when the state hydraulic paradigm gives way to new water governance frameworks.[13] However, for characteristics to be useful indicators of environmental change, urban society must be recognised as heterogeneous in terms of such attributes as cultural background, physical mobility, gender, age, level of formal or informal education, access to information and communication, purchasing power and political influence.[14] In this article, the idea of hydrosocial knowledge is understood as a basis for thinking and examining the interactions between socio–natural processes in which water and society alter and reshape one another through time and space.

C. Functional knowledge is a bridging knowledge set that connects water–related knowledge to real–world applications by underscoring the difference between how water is used currently, and how water should be used. It is a cognitive element that highlights knowledge about how to act or use water with a long–term perspective of water resources such that there is still adequate quality and quantity to supply future generations. This includes awareness of how to use water sustainably, conserve it, and protect and/or restore watersheds.[15] Referring to Lemos et al.,(2010), a better understanding of the factors that influence the application of technical knowledge in water management is critical for

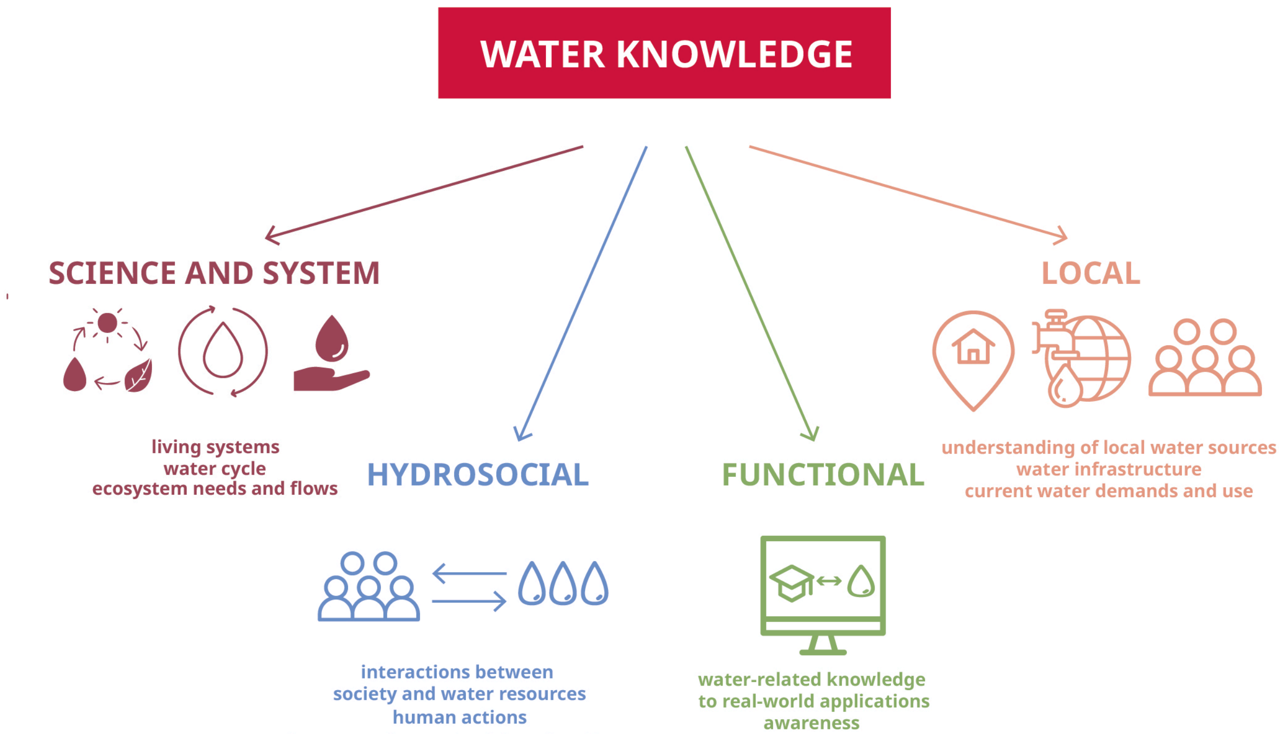


Figure 2: Main Components of Water Knowledge and its characteristics. Source: own compilation, 2022

increasing its relevance to decision–making and sustainable governance and informing knowledge providers about where gaps exist.
Effective water resource management is dependent on water governance as it lays down the principles under which water management works.[16] Since there are several stakeholders involved in urban water governance, cross–sectoral coordination and communication between governmental institutions and actors have become essential.[17]

D. Local knowledge, which encompasses an understanding of local water sources, water infrastructure, and current water demands and use. Each region and each city has a distinctive lifestyle. This lifestyle fits the available resources, including water resources, the climate, and the geographic character of the area.
Water knowledge is associated with age, education, and living area. It is highly recommended to examine the water knowledge of a community as it is an issue rarely examined in research. Considering the importance of community knowledge on water issues, and identifying knowledge gaps of potential communities that may require additional training to build that knowledge is considered a core ingredient of solving water–related challenges and supporting water management initiatives.

Methodology

Within the framework of research of the PolyUrbanWaters project, we began to assess the level of knowledge in the community and among the government officials in the Sleman Regency. Understanding the level of water knowledge will enable our project's research to better the gaps and therefore target engagement around issues that can benefit the village, regional and national government, the environment and people's well–being.
This research attempts to look at the different dimensions of the system through which knowledge on regard to water is achieved through different mechanisms and approaches.
A single case study was the focus of this investigation, hence a single–case study research strategy was utilised. The purpose of the case study was to examine the level of knowledge in Sariharjo Village's urban water resources management. The following viewpoints are taken into account, such as the viewpoint of communities in order to examine their level of water knowledge at the household and village level, the viewpoint of various experts from the village and regency government through interviews to better grasp the degree to which locals have knowledge of water resources.

A summary of the main discussed points reveals that the focus was on topics like water resources, governance, sustainable mechanisms, future water use, local knowledge, water quality and quantity, and challenges and opportunities. In the end, recommendations were given in order to improve the water knowledge of citizens and officials working in governmental institutions.

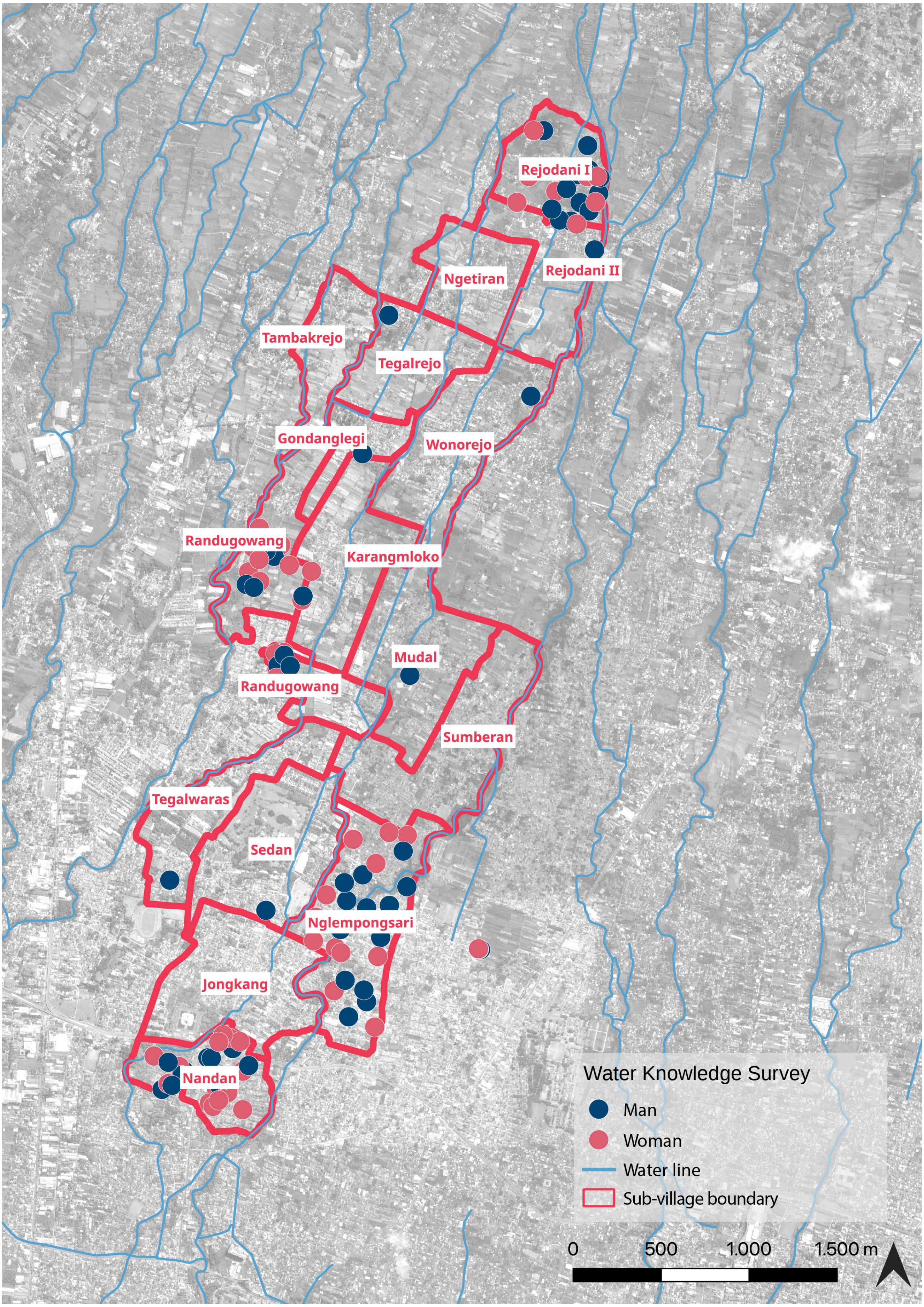
Results from survey

<u>General Information</u>
The distribution of the survey took place from April until the middle of May 2022. The survey was conducted by assistants in independent face–to–face interviews using the digital Kobocollect Toolbox, where not only the answers were recorded, but also the household locations and photographic answers/illustrations. The team conducted this survey primarily in the 4 related sub–villages of Sariharjo that represent different types of urban development patterns: urban – Nandan and Nglempongsari Sub–Villages; urban–rural – Randugowanang Sub–Village; rural – Rejodani I Sub–Village, with a total of 95 respondents, and single surveys were further conducted in nine other sub–villages in Sariharjo (18 respondents) (see Fig. 4).

Referring to the age distribution Table 4, it shows that the population of the responders represent middle age, respectively between 36 to 65 years old. The sample representatives who are younger than 36 and above 65 were less represented.

Of all respondents, 55% were having a middle education degree (Senior high school or equivalent) and 31.8% were having higher education degrees (first–degree bachelor, diploma and doctorate). Although this sample size should be representative for Sariharjo village, it's important to mention that the citizens who participated in the survey have a higher average ed-

Figure 3:
Sex–disaggregated data of participants in the survey.
Source: own compilation, 2022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Jongkang
Nandan
Water Knowledge Survey
Man
Woman
Water line
Sub-village boundary
0
500
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ucation level than the overall population of the whole village. The average number of respondents' household members was 4.

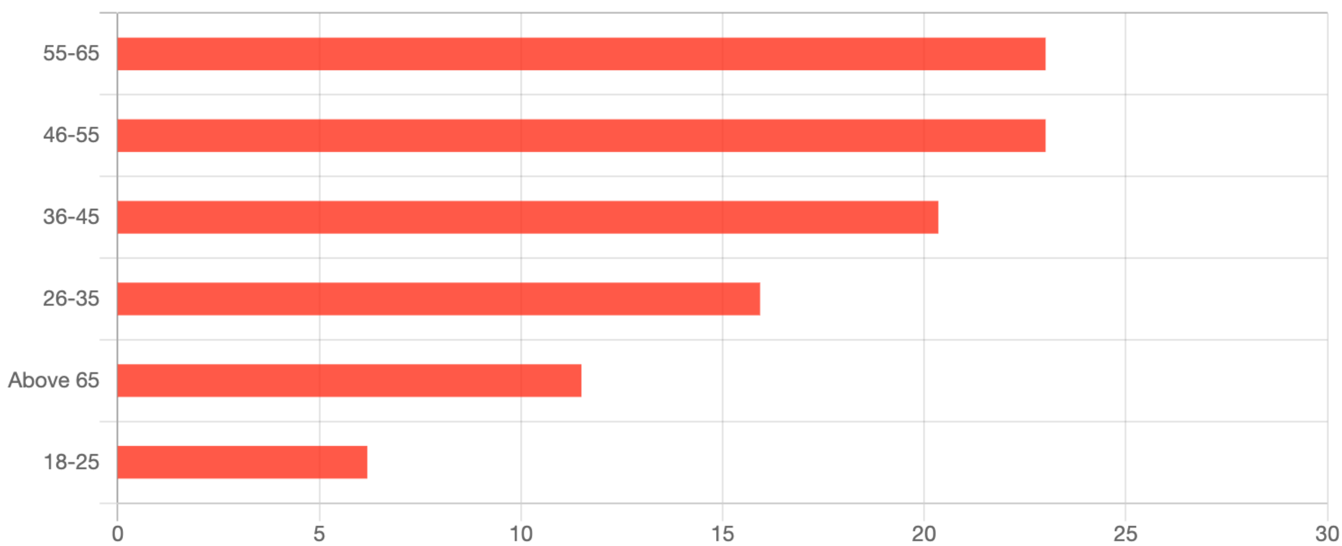
Water Knowledge Information
From 113 participants, asked whether they know what a water source is, 89.38% (101) stated yes and only 10.62% (12) stated no. From respondents who answered no, 50% were women and 50% were men and 83.3% were having lower education degrees (elementary/senior/junior high school) and were coming from lower income groups (>2500 Rupiah/month).

When talking about the identification of water sources, participants were asked to take a photo of a water source they could identify in their town, neighbourhood or house. From all 113 respondents, only one identified local stream as water source, all other participants identified either tap or deep well as a commonly known source of water in their surrounding (see Fig. 7). When asked about the title for the chosen photo, the answers ranged from 'water tap', 'groundwater well', 'water metre', 'house well', 'pipe connection' and many others similar to those listed above. Most of the answers were justified as follows by the respondents: the photo represents the main water source in my household/family.
Activities performed by the community (citizens, village residents) in connection to water resources

The participants were asked to identify the main reasons for water use in their households where multiple choices were available. Over 90% of respondents use water mainly for personal hygiene, cooking, laundry and cleaning. Almost 80% would use water for drinking, but only after boiling. 32% of respondents use water for gardening and less than 10% would use it for agriculture, fish ponds, businesses and others.
Subsequently, participants were asked whether they agree (0–not relevant; 1–never; 5–always) with the statements listed in the table below, relating to the activities linked to the water resources and ecosystem services (Annex Table 1). It seems that the green infrastructures and their functions in the ecosystem are fundamentally understood and used among the respondents, yet some answers suggest they are not entirely aware of the water bodies' quality and pollution. Contrary to our observations on site, most of the respondents claim the rivers are not used for swimming.
Furthermore, based on the respondents' answers to selected knowledge statements, it can be said that the communities are willing to participate more in water resources management and would like to extend their knowledge about water resources, planning processes and projects in their neighbourhood. (Annex Table 2).

In addition, participants were asked if they would be willing to pay a fee in order to ensure healthy water bodies, therefore improving citizens' well-being. 74% of respondents stated yes, augmenting it with such reasons as improved quality of water

Figure 4:
Survey respondents according to their age/number or respondents. Source: own compilation, 2022



bodies; potential investment of the finances in the improvement of the capacity and awareness of local citizens; four respondents were as well unsatisfied with the current water quality and services. 26% of respondents wouldn't pay higher water fees mainly due to no available financial resources.

Results from Interviews

1. Science and System Knowledge

The results of the interviews revealed that officials lack a basic understanding of the hydrological cycle (infiltration, evapotranspiration, evaporation, runoff, condensation, and precipitation), particularly in relation to the characterisation of human impacts on the water cycle. Hydrological research underlies the majority of water resource decisions and serves as the foundation for analysing water–related hazards such as floods and droughts.[18]

2. Hydro–social knowledge

Regarding water quality and quantity the scope is rather limited to water pollution, presumably because of the relative simplicity of the odour and colour of the water (pollution with iron and manganese). Although the water quality monitoring activi-

Figure 5: Survey respondents' education level/number of respondents. Source: own compilation, 2022

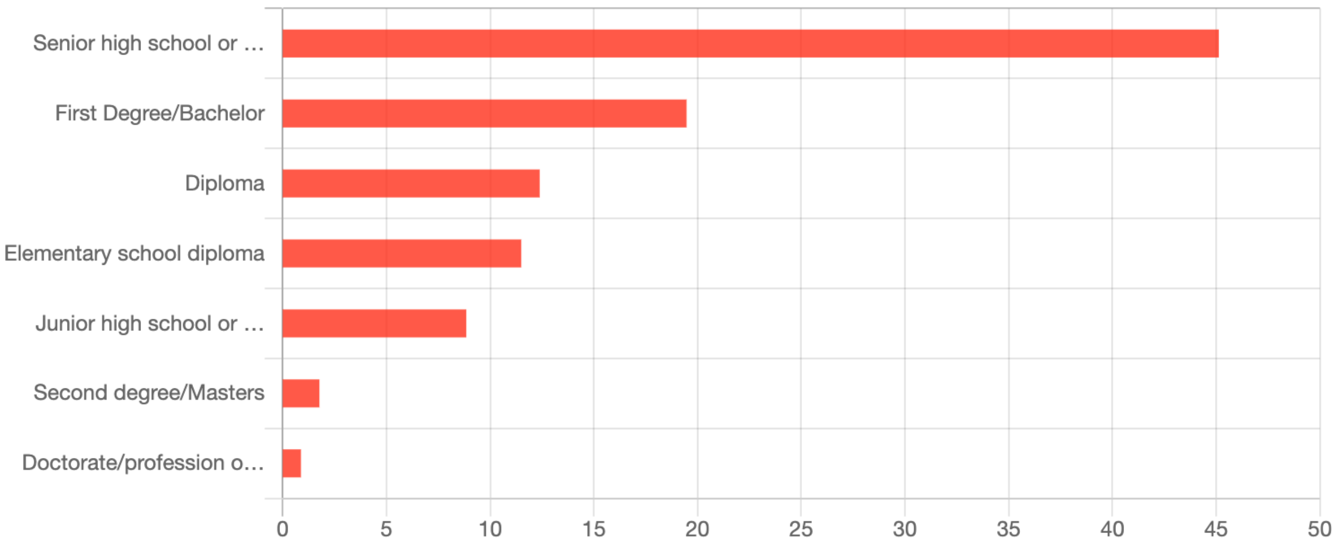


Figure 6: Do you know what a water source is? Source: own compilation, 2022

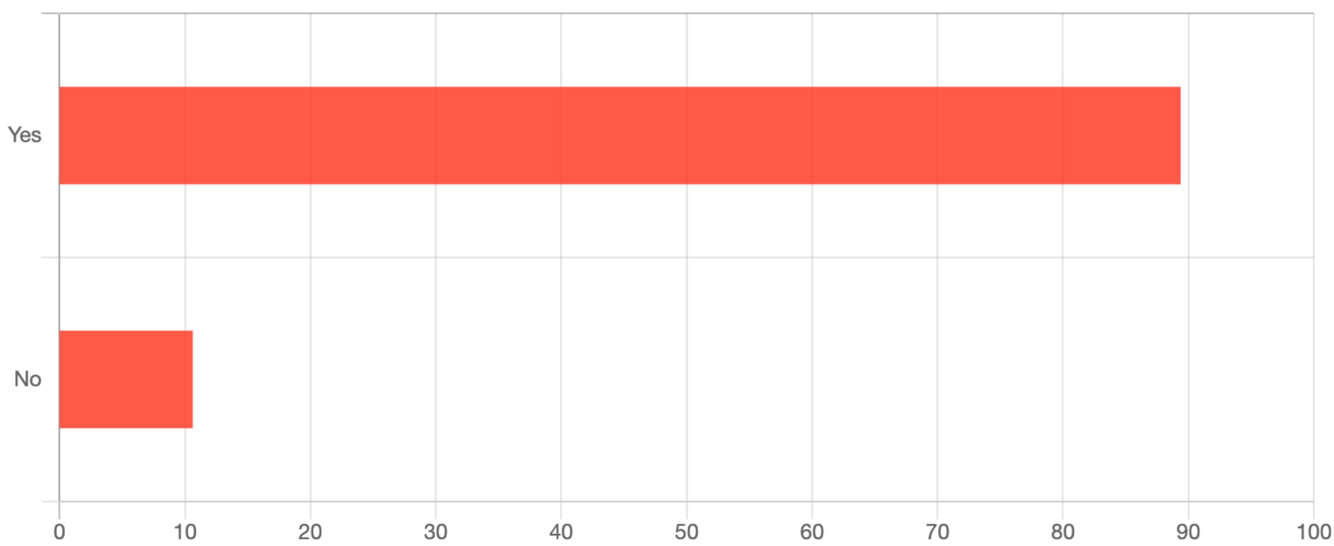


Figure 7:
Selected photos representing water sources indicated by the survey respondents.
Source: own compilation, 2022

ties are minimal, there are indications from official agencies that the water resources contain microbiological contaminants such as E.coli. Therefore, surface water and drinking water do not meet national standards.

About water quantity, experts revealed that water quantity is reduced due to factors such as natural disasters, surface water pollution and overexploitation of groundwater resources. Thus, it is crucial for local and provincial governments to pay attention to finding solutions that fulfil the needs of communities.

Droughts and floods: One of the most important services for humans is being supplied with water. Hydrological research underlies most of water resource decisions and serves as the foundation for analysing water–related hazards such as floods and droughts.[19] Despite its relevance, at Sariharjo village these areas are characterised by an acute scarcity of data and information, which contrasts markedly with the variety and complexity of actual water management and governance.

3. Local Knowledge

Local knowledge encompasses an understanding of local water sources, water infrastructure, and current water demands and use. In Sariharjo village water use is mostly related to personal hygiene (bathing, washing hands, etc.), farming, cooking, activities (for example washing clothes, cleaning the house, etc.), gardening, drinking water, tourism, fisheries, business purposes. Information on topics such as saving water, finding optional uses, utilising groundwater and controlling the pollution caused by activities are very limited in many communities.

Officials stated that the natural conditions of water resources in Sariharjo Village are still good and not prone to disasters, even though the population is growing increas-

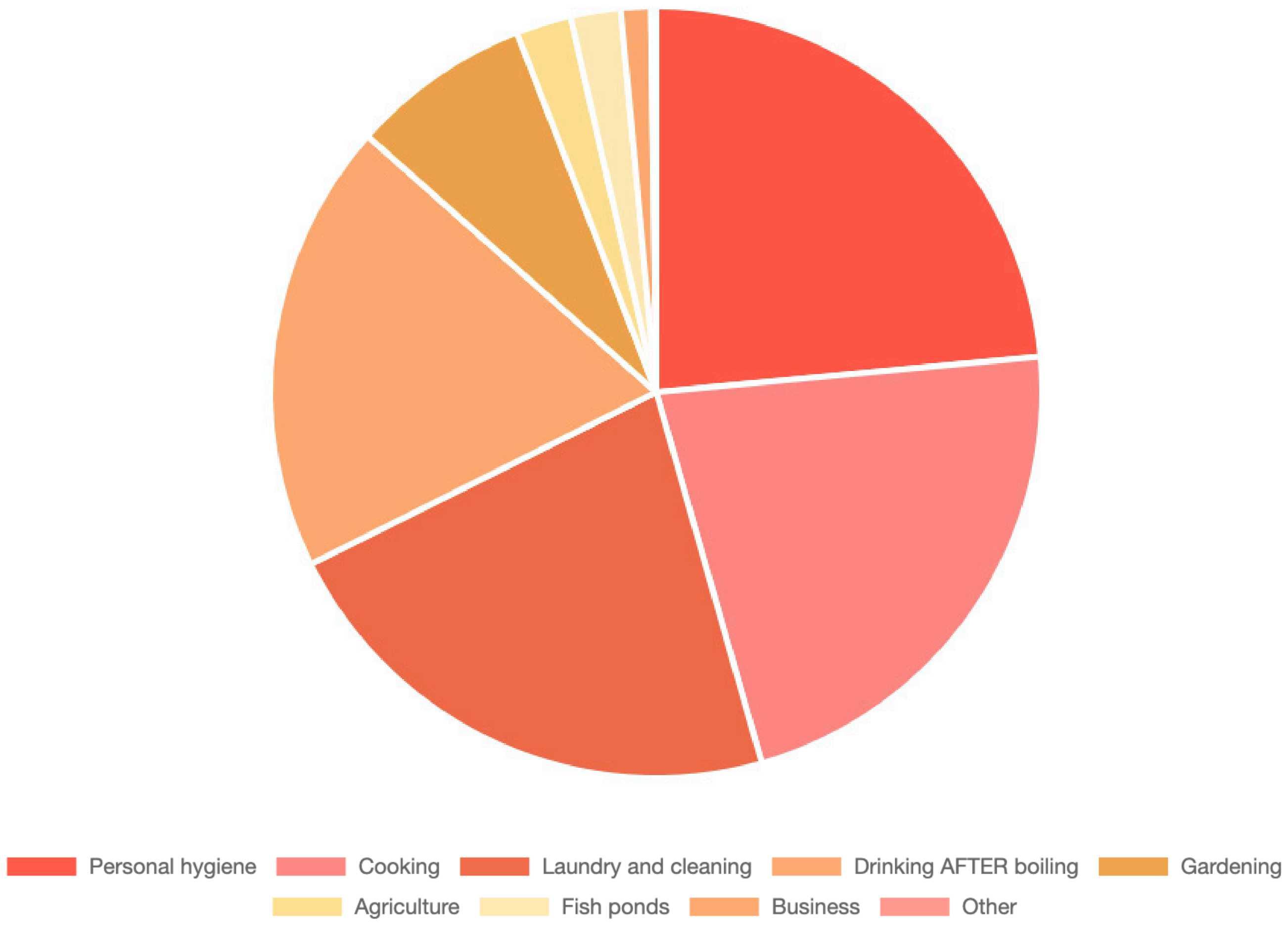


Figure 8:
Water use in Sariharjo Village.
Source: own compilation, 2022

ingly dense in the Sariharjo Village. On the contrary, they have noticed that flow of springs on the slopes of Merapi has started to decrease due to natural disasters, the quality of surface water has decreased, and groundwater reserves have been overused due to urban development. The population in Sariharjo village relies mainly on surface water and groundwater. The main water sources in Sariharjo village consist of sources such as rivers, lakes, reservoirs, and artificial lakes. Groundwater is used as the main resource for drinking water through private wells, wells from private companies that sell the water, and communal water tanks. Furthermore, there is no updated information regarding the condition of water resources and their network.
According to those responding to the interview, water demands for clean drinking water are higher in hilly areas where the infrastructure is not built yet Meanwhile, the challenges faced are usually community demands related to the costs incurred from managing these water resources. The local knowledge of the interviewed stakeholders can be assessed as satisfactory.

Water supply infrastructure is confined to community–based drinking water, and institutional management of such infrastructures must be improved. Water metres are challenging to install in some tough–to–access regions. Due to the lack of a proper water supply network, clean water from water provision does not meet national standards as a drinking water. Experts suggested changes in the technology of treating drinking water from conventional equipment (e.g., aerators, sedimentation, sand filters) to more advanced technology such as pressure filters.
Regarding wastewater infrastructure, most households are connected to not engineered septic tanks and only limited households are connected to a proper wastewater network.
Furthermore, wastewater treatment plants are community–based and lack knowledge of operational and maintenance. Neverthe-

	0-1 (0-not relevant, 1-never, 5-always)	0	1	2	3	4	5	I don't know
1	Crop fields, public and private gardens provide us with vegetables, root crops, fruits, etc.	19	2	2	11	49	26	4
2	Crop fields, public and private gardens provide us with herbal supplements, or for medical use.	19	0	2	12	51	23	6
3	Water from rivers and streams is used for swimming.	38	25	13	14	14	1	8
4	Water from rivers and streams is used for agricultural purposes.	24	3	4	4	33	40	5
5	Water wells are the main source of drinking water.	3	8	6	3	17	76	0
6	Water from water wells is used for agricultural areas and other activities outside the house.	15	4	12	18	46	15	3
7	Forests, rivers, and green areas are exposed to pollution, but they are still in very good condition.	26	2	5	15	21	23	21
8	Forest and dense tree areas along the river prevent the process of losing volume of soil.	2	0	0	11	41	57	2
9	Green areas, forest, and trees in the city have a great impact in slowing down the velocity and decreasing the volume of rainwater.	0	0	2	9	52	46	4
10	Throughout the city, infiltration areas are very well organised and maintained.	1	0	2	10	39	55	6
11	Forest, green areas in the city and along the rivers help to treat and clean the water.	2	0	1	9	46	54	1
12	Areas with high density of vegetation which help reducing CO_2 emission concentration.	0	0	2	7	41	60	3
13	It is very comfortable to stay in the forest, green areas and close to rivers because you can feel the breeze.	1	0	4	16	39	45	8
14	Parks, gardens, forest, and paths along the river are used for walking, jogging.	6	1	4	26	49	22	5
15	Parks, gardens, forest, and rivers are a nice place where you can enjoy the view and observe nature.	1	0	3	14	57	34	4
16	Parks, gardens, forest, and rivers are important for scientific research and educational activities.	2	0	2	10	60	32	7
17	Parks, gardens, forest, and rivers are important for tourist attraction in terms of culture, heritage, and spiritual reasons.	4	1	5	27	50	20	6
18	Parks, gardens, forest, and rivers are important for inspiration and have natural aesthetic value.	1	1	2	16	56	31	6
19	Parks, gardens, forest, and rivers are used very often for entertainment, eco-tourism and recreation activities.	2	0	2	16	57	31	5

Table 1:
Activities performed in connection to water resources.
Source: own compilation, 2022

less, village finances and voluntary work of the community are still limited, finances are still directed at the development of other infrastructure.

4. Functional Knowledge

There are certain factors that influence the level of functional knowledge in Sariharjo village. For the purpose of this study, topics that we took into consideration are:

A. Water resources governance with elements such as:

Actors: National institutions serve a critical role in ensuring that the legal framework impacts actions at all levels of government. They also devote attention to securing financing for projects and programmemes that influence citizens' lives, such as water supply infrastructure, wastewater infrastructure, solid waste infrastructure, and others. Even though the national government actors are focused on securing funding to promote these kinds of activities, the subjects of water resources management tend to ignore. However, there are factors that underlie this, namely, the lack of knowledge among the community and officials at different levels about water management, and the lack of space in urban areas to support these activities.
Although there are several stakeholders with basic functional knowledge involved in urban water governance, there is a lack of community representation as actors in decision–making because of limited invitations to them.

Legal framework: The set of policies issued by stakeholders in a specific region will have an impact on the activities carried out at all levels of governance. Policy and regulations are likely to have an influence on the way that water resources are perceived and managed. There is a set of legal frameworks such as laws, regulations, and rules available at the national, regional and local levels with regard to water resources, community involvement, managing drinking water and more.
Regarding the rules, they are put together internally according to mutual agreement at the village or organisation level. There is also a Regulation No. 27 of 2015, not requiring but protecting existing groups and implementing guidance at the village/sub–district level. Programmes for water quality monitoring and Drinking Water Safeguard Plan exist only for the drinking water purposes.

Financial mechanisms: The lack of support from the national government, limited budget allocation, limited funds of each authority holder are some of the reasons that are preventing local governments from planning and implementing integrated approaches for water resources. Moreover, the lack of village local government capacity to allocate budget resources from different government budget sources (from national to regency level) also hinders the implementation and initiative related to water at the village level. The village fund is one of the budget resources that could be used for water–related initiatives at the community/village level.
These projects require significant initial funding, especially when it comes to water supply and wastewater networks. Funding for these projects is carried out by the national and provincial government. There are also voluntary initiatives from communities to build these types of infrastructures, but the village finances and community self–help are still limited, finances are still directed at the development of other infrastructure.
At the district level, funds for data collection, water management training, competitions, comparative studies (and even more) are available, but the pandemic has significantly influenced the distribution of funds, due to allocation for different uses.

B. Sustainable mechanisms such as watershed restoration, protection and conservation are being considered

In terms of **watershed restoration**, experts advised that there should be a high demand on reforestation programmes and projects to conserve water resources (e.g. on riverbanks, water sources.). Currently, there are several reforestation programmes, among others such as planting trees or creation of buffer zones for infiltration wells, but the demand for similar projects is higher.
Referring to **watershed protection** as a sustainable mechanism, it has been disclosed that in the spatial planning of Sariharjo village efforts for establishing programmes with the aim of protecting water resources are made. Sleman Regency, but

	Knowledge statement	not relevant	strongly disagree	somewhat disagree	Neither agree nor disagree	somewhat agree	strongly agree
1	The run-off that drains through the land and is collected in specific river/streams is called catchment area.	9	0	7	9	72	16
2	I am aware which rivers run through my city.	8	0	0	5	42	58
3	Water conservation practices used by citizens can drastically reduce the amount of water used from the water supply system.	10	1	2	11	64	25
4	Activities taken by citizens can affect the quality of water bodies.	8	2	6	6	52	39
5	The fertilizers/pesticides that citizens use in their land for agricultural purposes have a negative impact on the water bodies.	17	4	16	11	33	32
6	Discharging industrial or household wastewater directly to water bodies without treating it before, does have a significant impact on the health of water bodies.	5	5	6	6	26	65
7	Water bodies can deal easily with large amounts of sediment (i.e. suspended matter in the water).	14	22	36	20	16	5
8	Planting native/local plants along a waterway's bank andbuilding healthy riparian zones improve the health of waterways.	5	0	2	5	53	48
9	Soil erosion affects the quality of water.	11	0	4	7	59	32
10	Raising awareness on protecting and conserving water bodies can improve the current condition of water bodies.	3	0	1	3	39	67
11	My family members and I are actively involved in the urban planning processes in my neighbourhood.	4	6	18	21	29	35
12	I would like to be more involved in the urban planning processes in my neighbourhood.	9	3	15	24	37	34
13	I would like to be more informed about the upcoming projects, programs in my neigbourhood.	1	2	5	28	47	30
14	I am aware of all of planned projects and activities in my neighbourhood.	13	2	7	31	38	22

Table 2:
Knowledge statement.
Source: own compilation, 2022

most particularly Sariharjo village is considered by the stakeholders as a water reservation area. Some of the indicators are the high numbers of water management groups at community level and activism activities from environmentalists that focus on protection of natural resources.
In reference to activities of **watershed conservation**, the current activities are limited to conserving water sources and springs, developing rainwater infiltration wells, and construction of infrastructure to harvest surface water as the main water source.

C. Future water use

Using data from the interviews, this article examines the use of current functional knowledge within these actors and their ability to make predictions for the future water use. It was revealed that there is lack of knowledge and a high need to reconsider establishing future water use plans (in terms of quantity and quality) at the local level with the current water needs to estimate new water sources to meet future water needs.

Interpretation of survey and interview results and discussion
The purpose of this article is to analyse water knowledge of experts and citizens in Sariharjo village. The applied framework provides thorough information on functional, hydro–social, functional and science and system knowledge. The information acquired from citizen surveys, expert interviews, field observations, and a thorough literature review helped us to identify the constraints and entry points for improving water sector knowledge.
The findings revealed that when it comes to Science and System Knowledge, there is a lack of consideration for scientific features and their importance for living systems. The hydrological cycle is not understood– separate components of the water cycle can be identified by the Sariharjo community, but its perception is not integrated into the cycle – one functioning system and its interdependencies.
The hydro–social knowledge and the interactions between social and natural resources and their influences are still very insignificant. There is an understanding that in many cases the water quality and quantity do not fulfil the national standards but would not instantly relate it to concrete human actions. The result of a lack of knowledge and education on topics of water resources.
Related to functional and local knowledge, the knowledge gap and the need for further capacity development and awareness building were clearly identified. In terms of the long–term perspective of water resources use and conservation, such that there is still adequate quality and quantity to supply future generations. Nevertheless, further research needs to be conducted. However, authors' interpretation demonstrates that there is rather no future, long–term thinking regarding water resources management, but short–term planning.

Recommendations and limitations
Based on the conclusions the following ***recommendations*** for future actions have been made:

Capacity building

It is crucial to understand that increasing the knowledge of citizens and local experts on topics of water resources would bring benefits to the social and ecological system of Sariharjo Village. In order to ensure a better understanding of topics related to water resources it is highly recommended to:
– increase knowledge among the citizens who tend to be 'busy' and do not have an active role in governing water resources in the village. Instead, they prefer to be subscribed to organisations which make decisions on their behalf.
Although individuals who participate in community organisations may not be representative of the general public, involving community organisations (PKP) and neighbourhood groups in water resource planning and management activities has fundamental and practical significance. Community organisations and neighbourhood groups, in particular, are well–positioned to approach citizens because of their non–government and non–profit status, as well as their volunteer and local nature.
It is essential to consider that establishing opportunities that incorporate and empower citizens will promote greater equity in the distribution of benefits from water resource decisions across participants. Furthermore, many levels and dimensions of empowerment must be considered to ensure citizen empowerment in

water resource planning and management. Based on interviews and activities in the field, it was observed that the community has local knowledge and capacity to initiate activities related to water and environmental issues.
The goal of empowered public participation is practical orientation and addressing immediate needs, citizen "bottom–up participation," and "deliberative solution generation," which involves participants listening to each other and generating group choices that are accepted in collective actions.[20]
It would be of high importance to invite citizens to public hearing sessions where topics of water resources management and urban planning are discussed. Especially if comparative studies are presented from other areas with better experiences such as Malang, Bandung, and Cilacap. Another potential space for the citizens to involve in the government decision–making process is through the participatory budgeting process called Musrenbang, which starts from the village to city/regency level.
However, experts suggest that is likely to lead to higher levels of knowledge in organising education sessions for the communities on how to save clean water and protect water bodies and the environment on important days such as World Water Day.
Experts recommend that citizens should be made aware of the necessity of using water from rivers an limiting the use of drinking water for household activities outside the home.
– increase knowledge among the governors that deal with topics of water management and urban planning. There is a high need to train experts from the local, regional and national levels on the topics of water management.
Furthermore, an increase in cross–sectoral coordination and communication between local government institutions and community organisations in Sariharjo would ensure the integrated implementation of water management practices at the local level.
Additionally, providing technical support to increase knowledge about improving water quality in surface water resources with iron and manganese is needed very urgently.

"Being water literate means having a basic understanding of how to use or manage the water sustainably as a manifest of understanding the importance and significance of the role of water in life and the relation between water cycle and social system."

<u>Raising Awareness</u>

Increasing public knowledge on water resource concerns is becoming increasingly vital as many water challenges require broad public support and understanding. Raising awareness clarifies water issues in matters such as water conservation, hygienic water use, and ecosystem preservation and disseminates information so that individuals can make their own, informed decisions. Activities to raise awareness should focus on two distinct areas such as.
– *<u>broader public awareness</u>*, which entails widespread recognition and comprehension of water challenges.
– *<u>self–awareness</u>*, which entails understanding the relationship between personal water consumption and environmental and societal consequences.

The **limitations** of the study create the opportunity of discussing potential follow–up actions for this research. Due to the time constraint, and therefore limited methodology, the semi–digital survey was addressed to only a particular number of respondents in selected sub–villages. Another limitation regarding the survey and interviews was the language barrier – these were first prepared in English and then translated into local language, which might have caused small discrepancies. The language barrier was also partially mediated through the facilitation or use of a translator/interpreter during the interviews.

Conclusions

Different types of water knowledge aspects have been proposed as a vital resource for implementing adaptive water resource management and strengthening the adaptive ability and resilience of sensitive water systems. The conducted research clearly demonstrates that basic water knowledge strongly influences the management of urban waters and is neccessary to ensure its sustainability. However, there has been relatively little empirical research assessing the role of local knowledge in water management in the case study region and even less exploring how it relates to broader institutional mechanisms within the context of emerging adaptive and integrated water governance approaches.[21]

At the same time, lack of consideration of the significance of functional, local, hydro–social, and science and system knowledge in water resources management suggest that more empirical studies need to be conducted in that field.[22]

1 Dekker et al., 2021
2 Abbot et al., 2019
3 Maniam et al., 2021
4 Dekker et al., 2021; Fulazzaky, 2014
5 Mulyana and Prasojo, 2020
6 IWA, 2022
7 Dean et al., 2016
8 Dean et al., 2016
9 AWC 2016
10 Rusca and Di Baldassarre 2019; McCarroll and Hamann, 2020
11 McCarroll and Hamann, 2020
12 e.g., Hannah et al., 2011
13 Linton and Budds, 2014
14 Andersson et al., 2021; Rall et al., 2017
15 McCarroll et al., 2020
16 Knieper and Pahl–Wostl, 2016
17 Mulyana and Prasojo, 2020; ADB, 2014
18 Buytaert et al., 2014
19 Buytaert et al., 2014
20 Watson, 2014; Fung and Wright, 2003
21 Pahl–Wostl et al., 2007
22 Lemos et al., 2010; Maniam et al., 2021

Matthew Dalrymple, Johanna Westermann

Water Resilient Urban Design and Planning

Testing an adaptive approach Sariharjo, Sleman

The represented approach to water resilient urban design and planning accepts the high level of uncertainty and risk that is inevitable when working in rapidly urbanising areas and offers a flexible and dynamic set of tools that can be used to achieve the Sustainable Development Goals on a local level. By proposing a decentralised and incremental approach to urban design, it allows for a higher level of flexibility when dealing with unknown influences such as climate change, social interests, and inconsistent project funding. The proposed catalog of tools compiles interventions whose implementation contributes to the achievement of global sustainability on a local level, while also leveraging investments in water–related issues to achieve community goals. This approach understands water as a vital resource and key asset in the development of sustainable cities, as well as a catalyst for helping communities reach their own goals around resilience, environmental hazard reduction, sustainable resource management, disaster preparedness and awareness, as well as equitable economic growth and social cohesion. In this sense, this proposal is not to be understood as a finalised design or ready–made concept, but rather it provides ideas and impulses for a different approach to urban planning and urban water management.

A Dynamic Approach to Water Resource Management

This design proposal aims to increase urban resilience, through the approach of Water-Sensitive planning. It recognises the fact that building urban resilience requires a cross–sectoral, multidimensional, and dynamic approach to planning. Achieving this goal requires reducing the vulnerability and exposure to environmental hazards, stimulating economic and social development without compromising the environment, and creating incremental egalitarian development opportunities. Enhancing social cohesion may increase a community's capacity for disaster preparedness and response.[1] Therefore, we elaborate the idea not only on physical aspects but also on social processes.

The complexity of urban systems and the uncertainty of natural hazards and climate change impacts limit a 'one solution fits all'–planning approach and requires an adaptive and flexible approach. In response to the static nature of traditional planning approaches, this design proposal seeks to explore the advantages of an adaptive planning approach that is responsive at the local level. Accordingly, this design proposal works with a set of small–scale interventions that can be implemented independently but ultimately contribute

"Given the diverse local conditions, small–scale interventions improving partial urban conditions referring to the individual spatial settings may be more effective than large–scale planning approaches."

to achieving the same goals. Given the unpredictable local conditions, small–scale interventions responding to the individual spatial settings can be more effective than large–scale planning approaches. Furthermore, this proposal assumes that successful implementation of the goals requires the participation of different actors, at different administrative levels and from different sectors. Each actor can contribute according to their own capacity and thus strengthen the capacity of the city as a complex system of human and non–human actors to cope with future challenges.

Possible interventions include the following:

Greening interventions – such as street trees, vertical greening, green roofs, bioswales, constructed wetlands and permeable paving systems – all refer to the greening of individual houses and properties, including interventions on the street level.

Figure 1:
Expected transformation corridors in Sariharjo
Source: Johanna Westermann, Matthew Dalrymple

Water-Sensitive Resource Measures – like rainwater harvesting and greywater recycling– relate to storing, recycling, and water harvesting measures that can be implemented on different scales. Water-Sensitive Urban Design Measures include a more engineered approach in the development of public spaces and green areas. These interventions can also be implemented in existing neighbourhoods but require more planning beforehand and a larger financial investment for both the construction and maintenance.

River Restoration measures – such as riverbank setbacks, channel widening, and floodplain restoration – have a specific focus on river systems and are otherwise similar to the water-sensitive urban design measures in terms of planning processes, financial investment, and maintenance.

Landscape Management tools like creating a watershed conservation area or diversifying local crops are interventions that could be implemented on a policymaking level.

Site Overview

The Special Region of Yogyakarta (Daerah Istimewa Yogyakarta or DIY) is a provincial–level autonomous region in southern Java. The city of Yogyakarta is the capital and economic centre of the region, and an important culture and education centre for Indonesia.

The area is dominated by Mount Merapi, an active volcano located approx. 28 km north from the centre of the city of Yogyakarta and the Indian Ocean in the south. Three main rivers, with an extensive system of man–made canals and natural tributaries, shape the region's landscape: The Gajahwong River in the east, the Code River in the Centre, and the Winongo River in the western part of Yogyakarta city.

The Special Region of Yogyakarta is home to 3.5 million people, with the highest density in the city of Yogyakarta. The region's population has been continuously growing in the past decades, forcing people to settle on vulnerable land along the rivers in the city centre and resulting in extensive development in the Bantul and Sleman, enlarging the urban area of Yogyakarta.[2]

The selected neighborhood, Sariharjo is

located in this peri–urban fringe of the Urbanised Area of Yogyakarta that has undergone a profound transformation in recent years. Sariharjo runs north–south along one of the main arteries of the city. The southern parts of Sariharjo are integrated into the urban areas of the city and accordingly dominated by spatial density and urban use, while the northern parts of Sariharjo are still dominated by agricultural use with an occasional building structure and single–family residential housing. Further growth and rapid development in Sariharjo are expected in the coming years, given its proximity to the city centre.

The diversity of urban typologies and land uses in Sariharjo allows for testing the implementation within different settings. The implementation of water sensitive urban resilience tools is considered in two of the different settings. Here we can see how our adaptive approach is able to meet goals of disaster preparedness, sustainable resource management, equitable economic growth, and increasing social cohesion in a variety of different contexts.

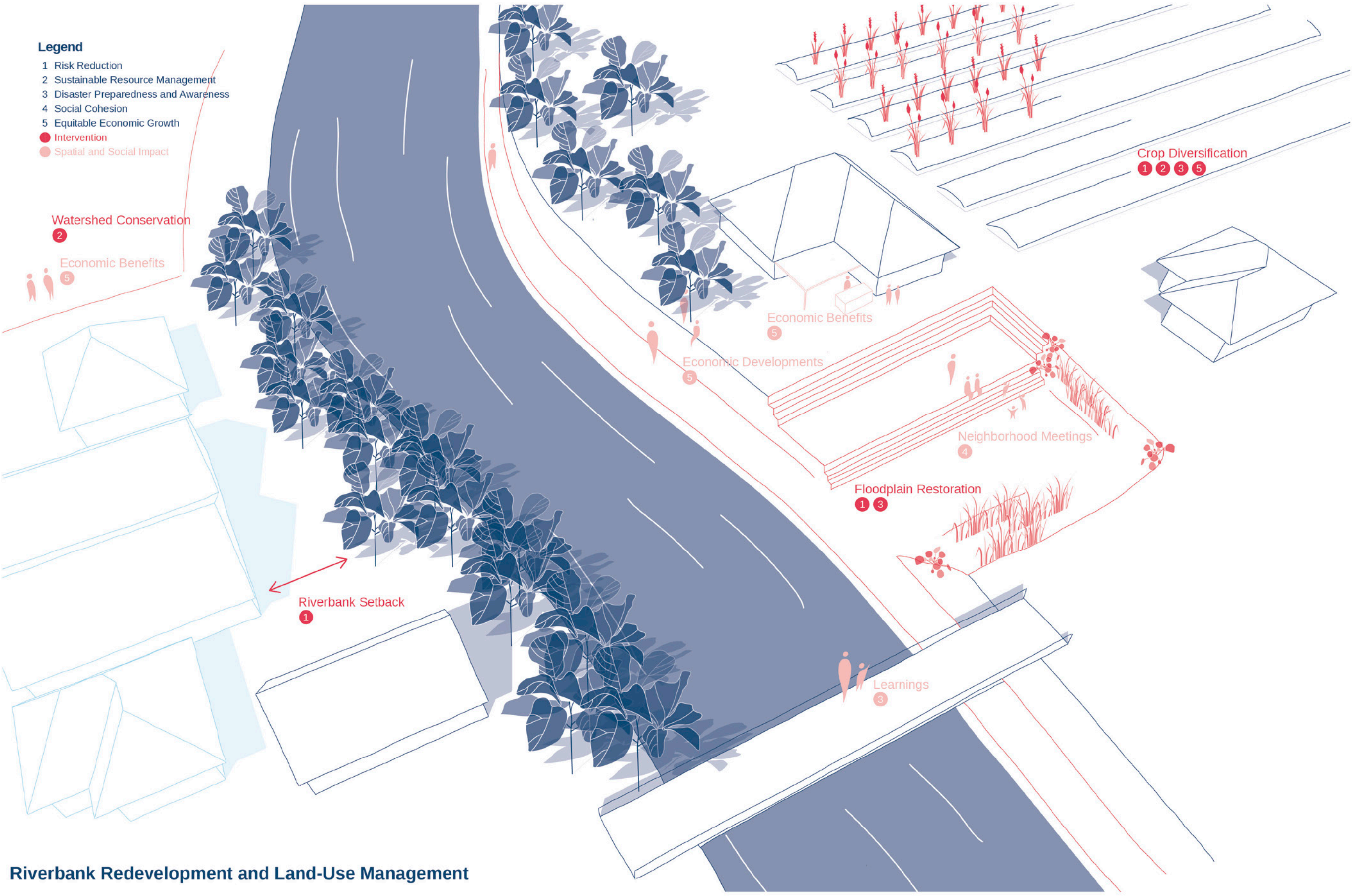
Northern Sariharjo on the Code River

The northern area of Sariharjo is still dominated by agricultural uses, as it plays a fundamental role for the food supply of the entire region. Protecting agricultural land and the food supply chains is therefore of high importance. However, the current system of monocultures is not very resilient to climate change uncertainties. Diversification of crops, which is historically culturally anchored in Indonesia[3], could offer a possible solution, and therefore be promoted and subsidised by state authorities.

Additionally, designating areas for watershed conservation in the northern areas of Sariharjo and Sleman to preserve the quality of the water at its source is important. The designated areas, however, can still be accessible as a nature reserve and thus strengthen ecologically sustainable tourism in the area.

The land in the north of Sariharjo is not as densely developed as in the south, and accordingly, it is easier to implement larger interventions, e.g. available land could be used to restore the floodplain areas. The following graphic illustrates that a flood-

Figure 2 :
Riverbank Redevelopment and Land–Use Management Scenario 1
Source: Johanna Westermann, Matthew Dalrymple



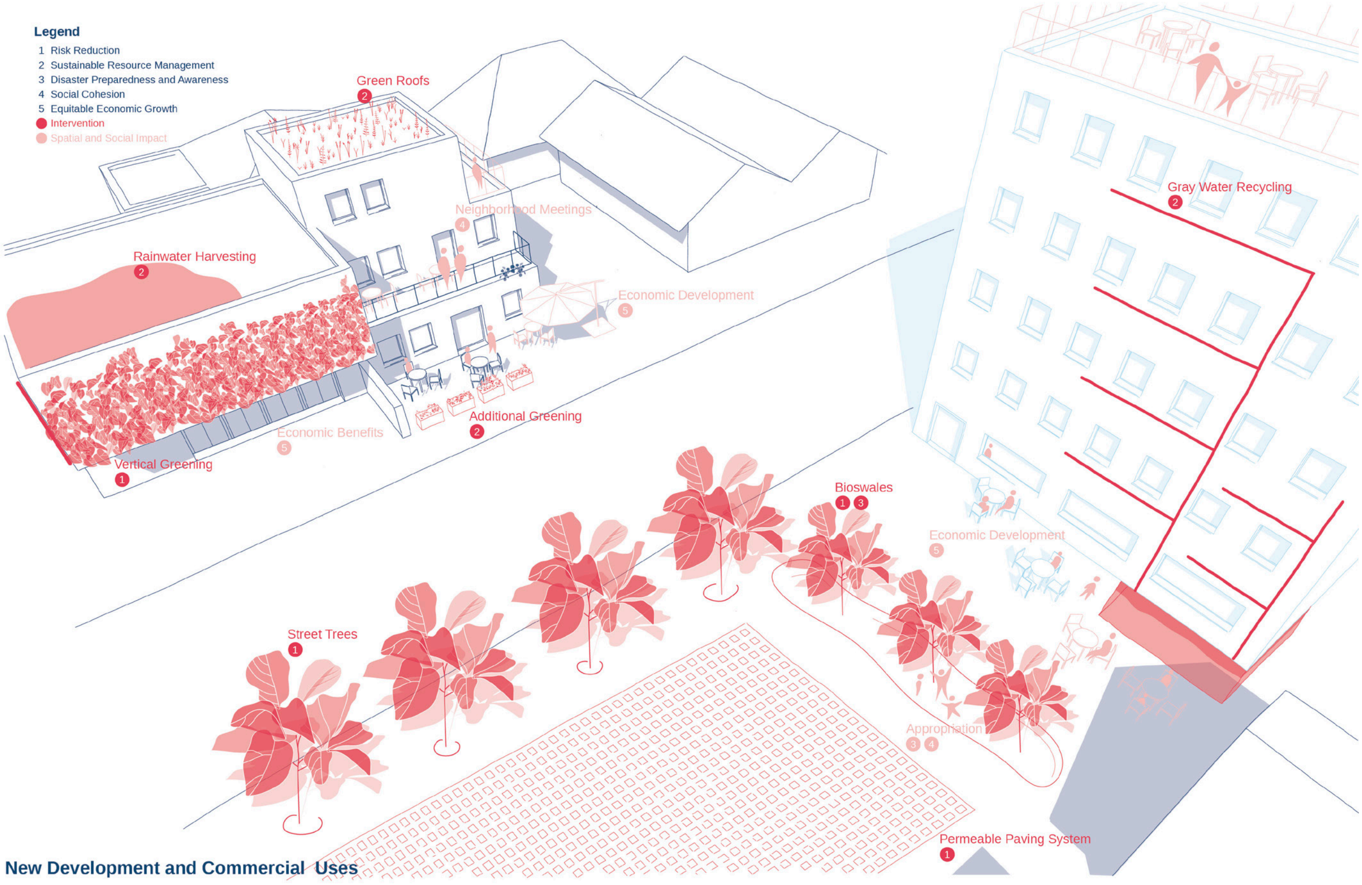


Figure 3:
New development and Commercial Uses Scenario 2
Source: Johanna Westermann, Matthew Dalrymple

plain restoration can be designed to take pressure off the riverbed during floods and heavy rainfall events[4], but also used as a recreational area when the water level is low.

Even if the riverbed in the north of Sleman is very deep and the risk of flooding is low, there is an increased risk of landslides after heavy rain events. In order to ensure the safety of new developments, they should keep a distance from the river. This transition zone could potentially be designed as a public space.

Southern Sariharjo in the Commercial District

The main arterial roads in Sariharjo are dominated by dense built–up areas used for trade, retail, or hospitality sector and are likely to develop further in the coming years. While many restaurants, for example, extend their outdoor seating area toward the streets, the quality of stay is highly affected by the intense traffic.

Green interventions on adjacent buildings and in the streetscape have the potential to improve the microclimate, water and air quality. Furthermore, they help to reduce the risk of urban floods, given their potential to store water and improve water infiltration[5],

Certain measures, such as vertical greening and rainwater harvesting in retail and commercially used buildings, which often have a physical structure predestined for such interventions, can result in economic benefits by reducing energy and water consumption. For individual owners or owner associations, such economic benefits can function as incentives to assume responsibility for the implementation and maintenance of greening interventions (Eisenberg and Polcher, 2019).

The graphic illustrates how green interventions can be utilised to create protected and high–quality outdoor spaces, while improving microclimatic conditions. In the case of large–scale development projects, as they are typical along the main arteries of Sariharjo, a sustainable Water-Sensitive approach can be incorporated into the development from the design process onwards. The example illustrates the implementation of a permeable paving system, street trees, and a green roof, which again helps to improve air quality and the microclimate. Additionally, the development works with grey water recycling to reduce the pressure on groundwater aquifers, and adds an economic benefit, given the resulting water savings.

Conclusion

The design proposal promotes a decentralised and local approach to global sustainability goals while promoting resilience. However, successful implementation is highly dependent on the participation of a wide range of actors, not only from different levels of government, but also – and in particular – from the local population. And for this, a common vision is necessary that ensures a consensus on the agreed goals and objectives. Elaborating such a vision in a participatory manner helps increase the possibility of identifying with the project and thus creates a sense of community and willingness to make efforts for a successful implementation.

Nevertheless, the design proposal aims to demonstrate that small interventions in localised sites can have an impact on a larger scale, therefore presenting an alternative to the top–down, large–scale planning approach. With regard to uncertainties about future development dynamics and the effects of climate change, such a small–scale, incremental planning approach helps to adapt to the rapidly changing conditions resulting from the urban development processes, socio–economic developments in fast–growing cities as well as the impacts of climate change.

In addition, the project elaborates on the potential of thinking about alternatives for the management of water as a resource and reinforces the fact that water is a cross–sectoral issue that can act as a catalyst for further spatial and social transformation processes.

1 Mucke et al., 2019
2 Höferl & Sandholz, 2017, p. 24
3 Christanty et al., 1986
4 Eisenberg & Polcher, 2019
5 Eisenberg & Polcher, 2019

Eka Permanasari

Water Ceremony

Improving ecosystem services through cultural practices in Petung and Brayut Vilages

Sleman Regency is located in the Special Region of Jogjakarta where the area 87.66% is mostly dominated by rice fields. This regency has an area of 574.82 km^2 and consists of 17 districts and 86 villages. According to the statistics in 2016, total population in Sleman is about 1,180,479.[1] In Sleman Regency, high rainfall is located in the north–west (Kaliurang, Turi, Tempel, Sleman, and north of Yogyakarta City) with rainfall greater than 2,500 mm / year, while in the east it has relatively lower rainfall, namely in the Ngemplak, Prambanan, and Kalasan areas (500–750 mm/year) (Sleman, 2017).

The river system in Sleman Regency has a radial–paralel pattern which is divided into 2 sub–systems namely the Progo and the Opak river subsystems [Figure 1]. The rivers that flow into the Progo subsystems include the Krasak river, Putih river, Konteng river, Jetis river, Bedog river. While the Opak subsystem includes Denggung river, Winongo river, Code river, Gajah Wong river, Tambakbayan river and Kuning river. To conserve water, the Sleman Regency

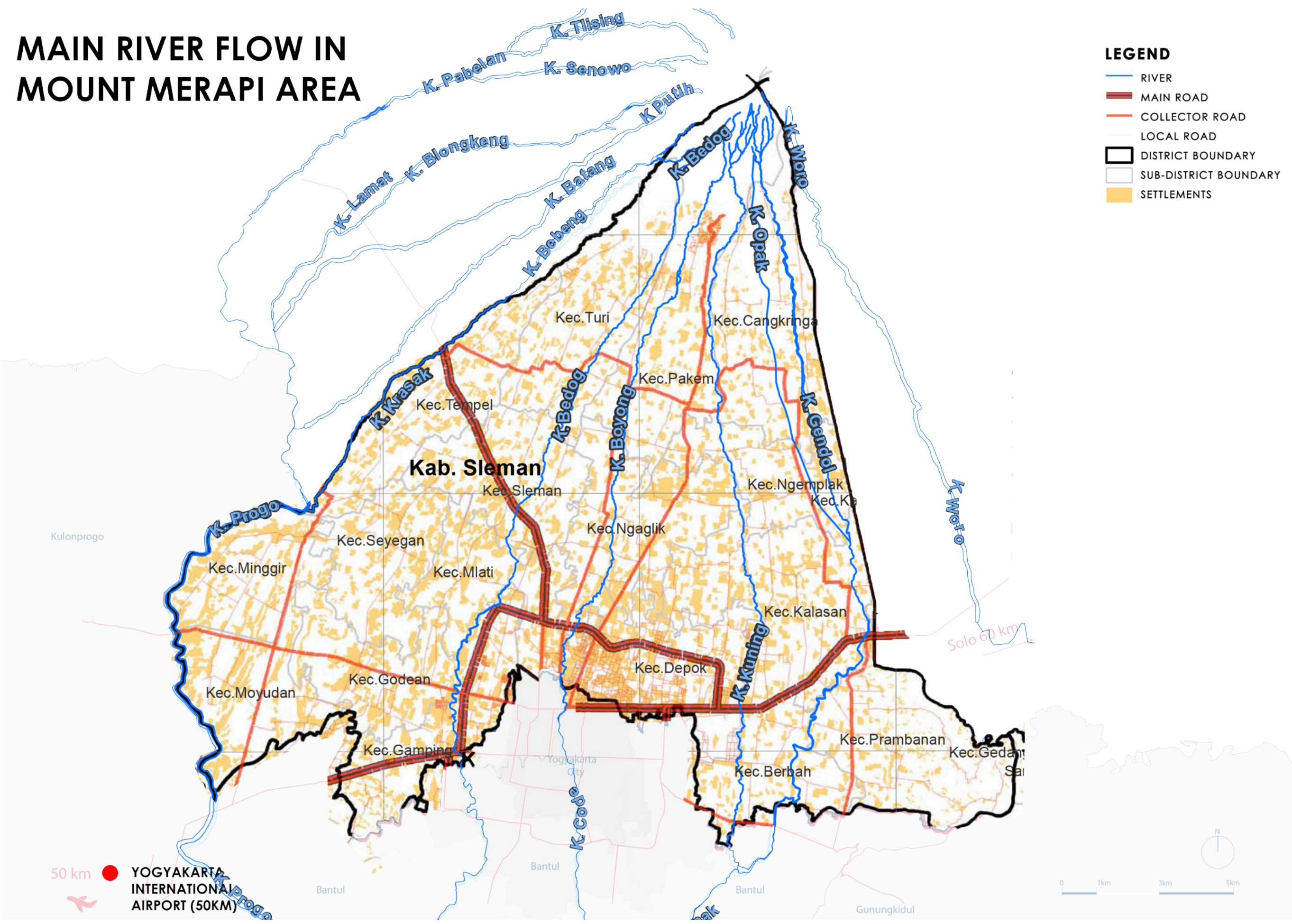


Figure 1:
River network in Yogyakarta
Source: Pemkab Sleman, modified by Author, 2020

Government built several common pools, namely: Candlenut, Karanggeneng, Tambakboyo, Lampeyan, Gancahan, Krajan, Jering, Muncar, Agro Tourism, UGM Valley, Jurugan, Temuwuh and Shaved. These reservoirs are used as a source of raw water and for agricultural irrigation (Sleman, 2017).

Sleman has a rapid urbanisation development. The map shows the number of settlement grows from the Jogjakarta Urban Area towards the northern part of Sleman (Mount Merapi). The changes are driven by the development of Yogyakarta Urbanised Area where the development of the new Yogyakarta International Airport (YIA) in Kulonprogo, tollroad connecting Yogya to neighbouring cities as well as new main roads (Jalur Lingkar).[2] The development of Yogyakarta New International Airport has changed the infrastructure of the city where new tourism areas are connected to the toll roads, highways and ring road. This has impacted all the rural villages that were transformed into village tourism [Figure 2]. The spatial expansion beyond the Yogyakarta Urban Area is due to the mega urbanisation process which pushes the city boundary to grow larger and form urban agglomerations. The city becomes 'mega' in terms of geographic form and scale.[3] The regencies have changed into urbanised areas as the rapid growth of mega–cities have reached unprecedented scales.[4]

In addition, land use intensification through mega projects has changed the urban morphology of the city into denser and higher volume construction. Mega projects include the development of large–scale infrastructure such as airport, railways or highways[5], iconic buildings[6], new redevelopments or sports mega events. These projects represent the drivers of urbanisation.[7] The changes occur both in the urban fabrics and in the social interaction between the locals and the tourists. Tourism villages become more globalised. The peripheral area becomes more urbanised and the ecosystem services are at great risks.

The rapid urbanisation process add certain problems to the regions such as land transformation, poor transportation network and pollution. The environmental degradation can be seen from poor drainage system, untreated solid and liquid waste

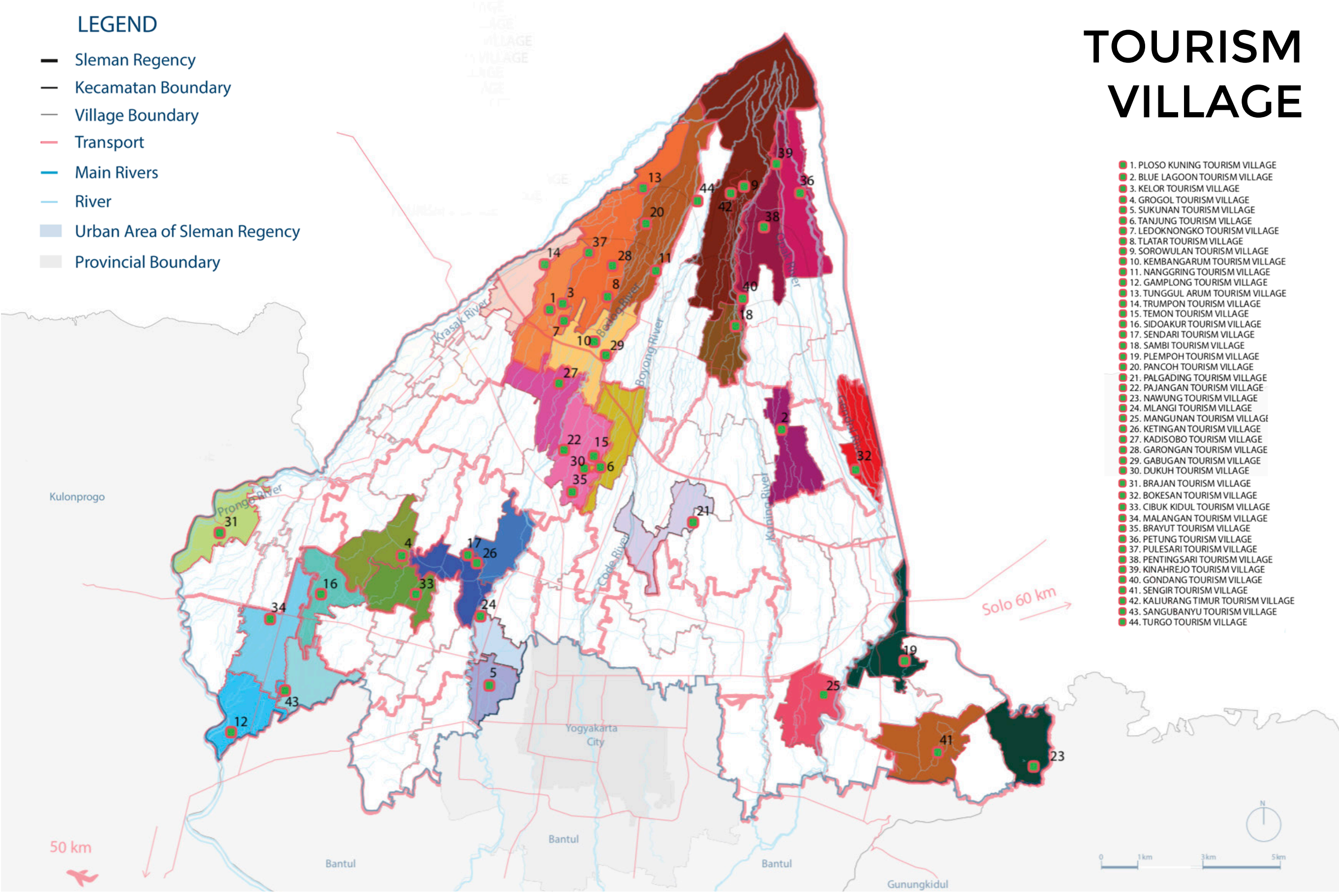
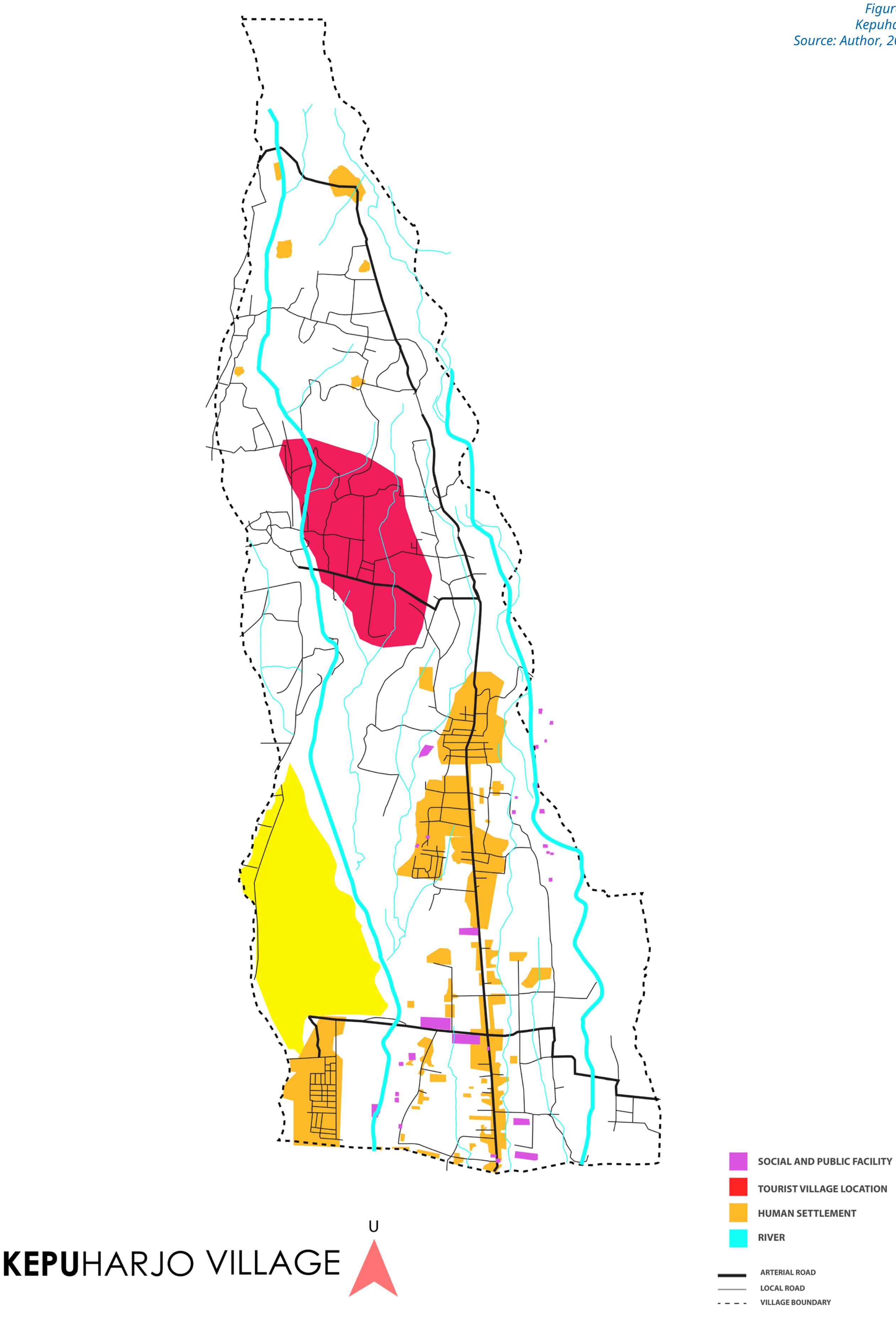


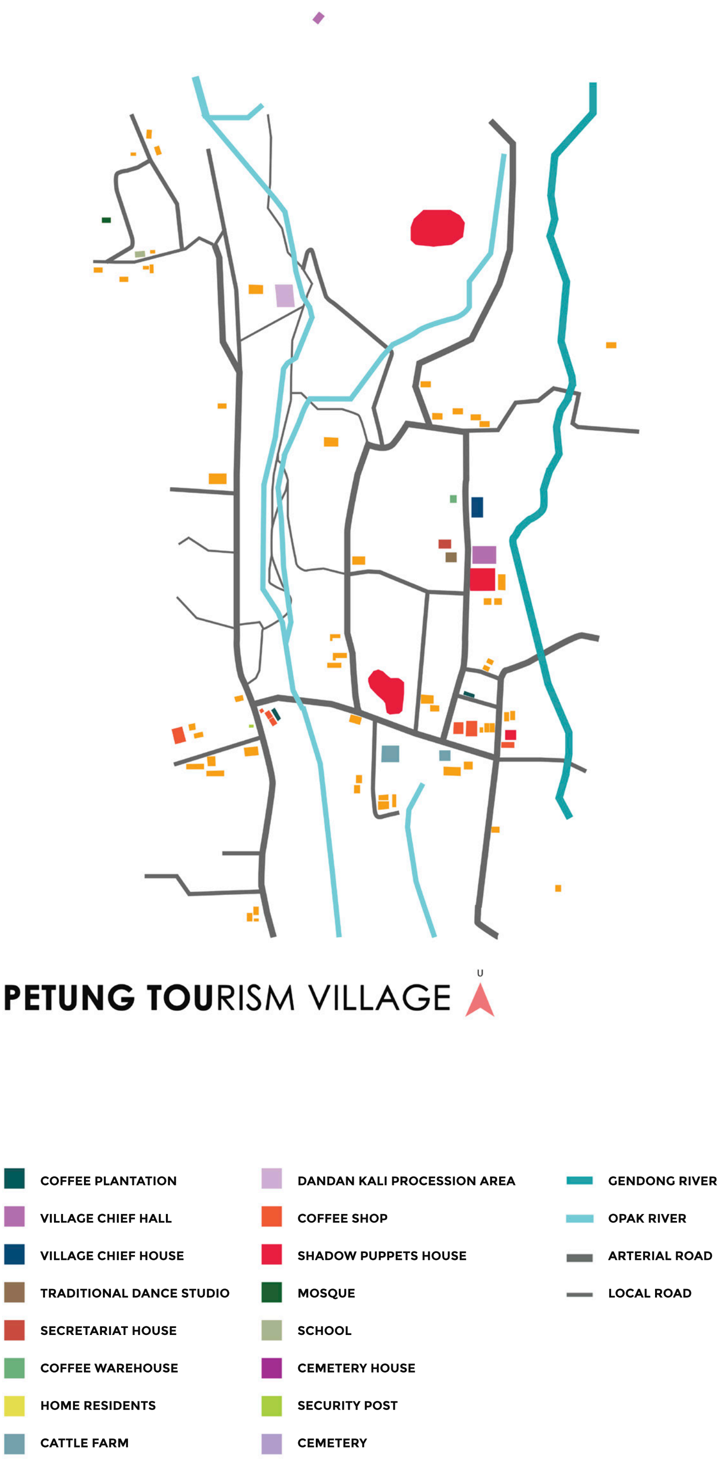
Figure 2:
The growing numbers of village tourism
Source: Author, 2020

Figure 3:
Kepuharjo
Source: Author, 2020



discharge directly to the river.[8] There are several attempts to improve the ecosystem services in rural areas of Yogyakarta through cultural practices. This paper will look at two river ceremonies in two tourism villages of Petung and Brayut Villages in Sleman. These two villages are taken as examples as they have similarities in preserving the environment through cultural performance and community participation.

Figure 4:
PPetung tourism village
Source: Author 2020



The ritual performances have been passed through generation and became the identity of these areas.

Cultural practices to preserve ecosystem services

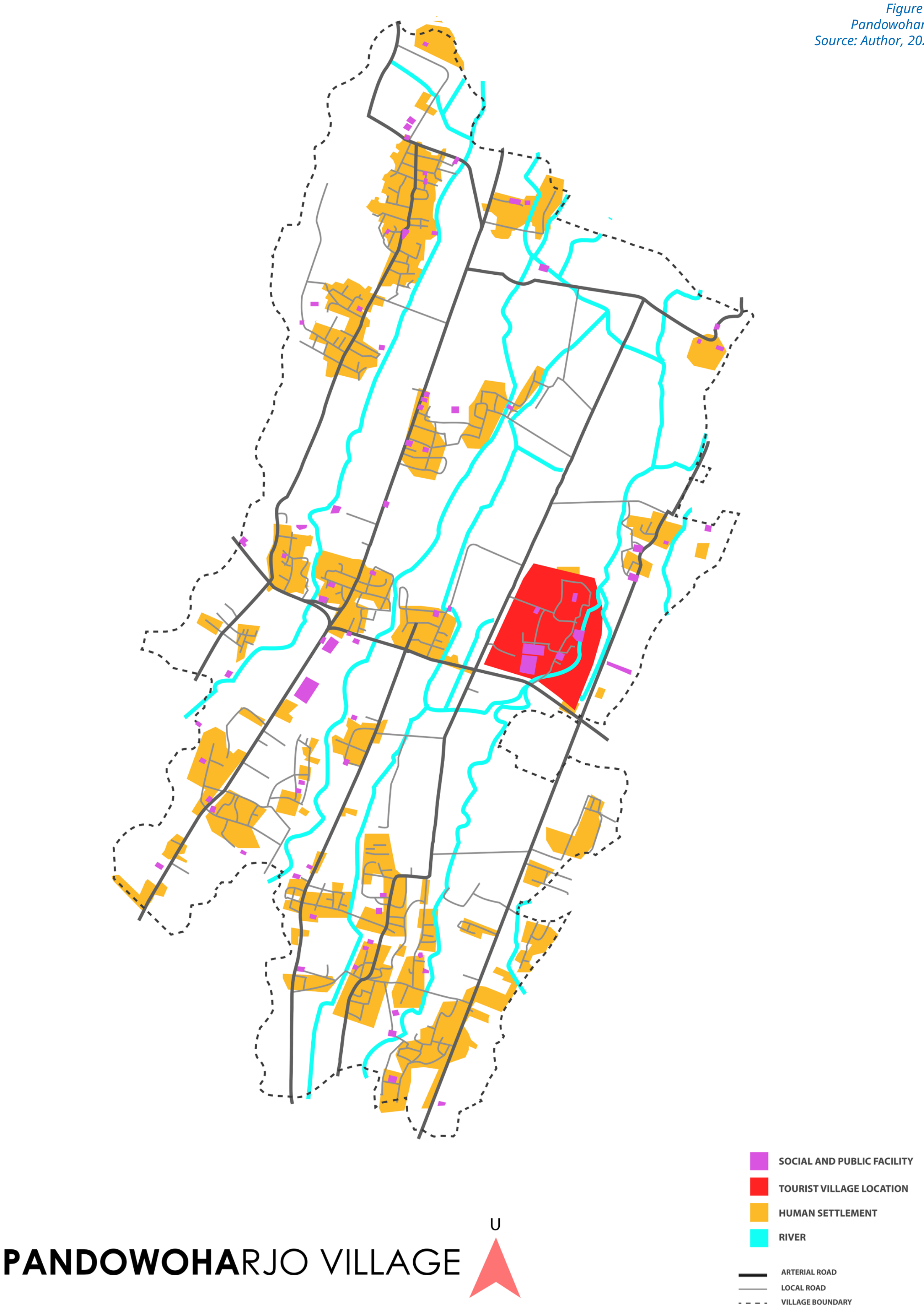
Cultural services are defined as the contribution of the ecosystem towards the human in non-material benefits (e.g sense of experience and feeling good), as the result of human-ecological relation.[9] However, this definition tends to focus on the result of what nature gives which impacts humans, and often overlooks the fact that there is a historical and long term interaction between human and nature. This relationship is reciprocal and can be explored through anthropology and history. Understanding this from a long-term perspective of human-nature relationships will help us define long-term environmental cycles and socio-ecological processes. Here, we will analyse the attempts to which cultural practices in Petung and Brayut Villages in Sleman improve the ecosystem services in rural areas of Yogyakarta.

Petung Village

Petung Village is one of main tourist attractions in Kepuharjo, Cangkringan, Sleman Regency. Petung has long history of water crises [Figure 3]. The area is categorised as middle to high water crisis level. The community tries to preserve the water by having Dandan Kali tradition which includes cleaning up the river and performing ritual such as animal sacrifice and ancestral offerings. Dandan Kali tradition (River beautification tradition) has been carried on for generations by the people of Kepuharjo. However, the ritual is only performed by men as women are not allowed to join the ceremony. The procession took place from the village to the Gendol river and performed the ritual. Using the uniform, the men headed to the river Gendol while marching and chanting.

This peak ceremony is carried out in the middle of the Gendol River as part of cleaning up, beautification and ritual ceremony. Apart from cleaning up the river, the men slaughter the sheep as part of the sacrifice, clean them and cook them on the site. The cooked meat then is distributed to the community in the village. The cultural practices link the river to the realm of God and at the same time to the realm of humans. Here, the balance of co–existence between

Figure 5:
Pandowoharjo
Source: Author, 2020

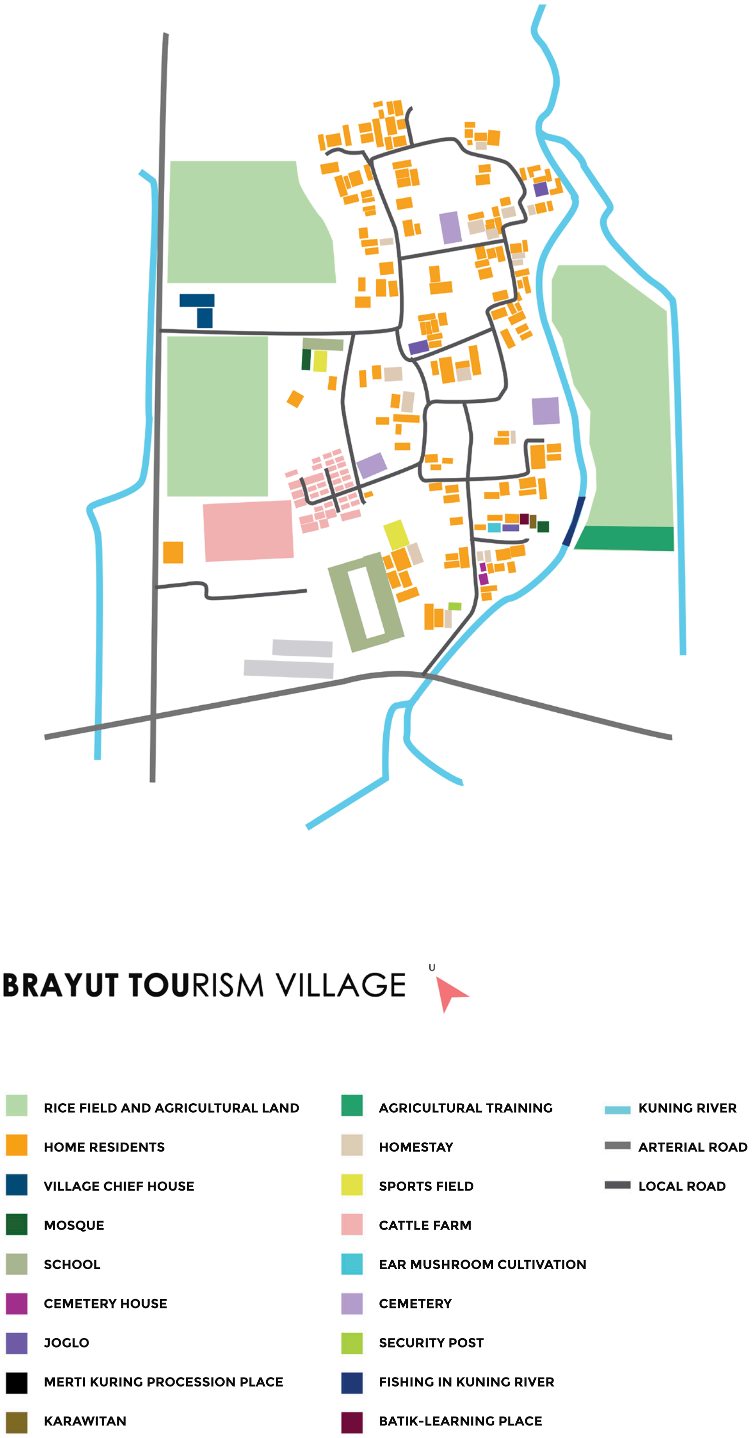


God–human–nature is established. The ceremony is held once a year as part of a ritual asking for rain to ensure the water keeps flowing to their village. It is deeply rooted in tradition and part of the community's involvement in forming Water-Sensitive community.

Brayut Village

Brayut tourism village located in Pandowoharjo, Sleman has an area of 35 hectares and was established on 14 August 1999.

Figure 6:
Brayut tourism village
Source: Author, 2020



Brayut village has an agricultural base and heavily relies on the river for irrigation purposes. The sign of an environmental crisis appears to be a decrease in the amount of water discharged in the rice fields of Brayut village, as well as a decrease in irrigation water availability in the dam [Figure 4].

In order to improve the ecosystem service, the community perform ritual practices on agriculture and river cleaning (Merti Kali ritual practice), in Kuning River. This event is aimed to maintain the cleanliness and sustainability of the Kuning River as the main source of a number of rivers in Sleman. The procession in this event includes bringing offerings, cleaning up the river, spreading fish seed, planting coconut trees, performing dance, praying and eating together. These ritual practices are performed on the water by female, male from different ages. Similar to the Dandan Kali ritual practices, Merti Kali Kuning is carried out to improve the quality of rivers in Sleman Regency. The cultural practices ensure the sustainability of the river while at the same time create social bonds, place attachment and spiritual understanding between the communities and their ecosystem.

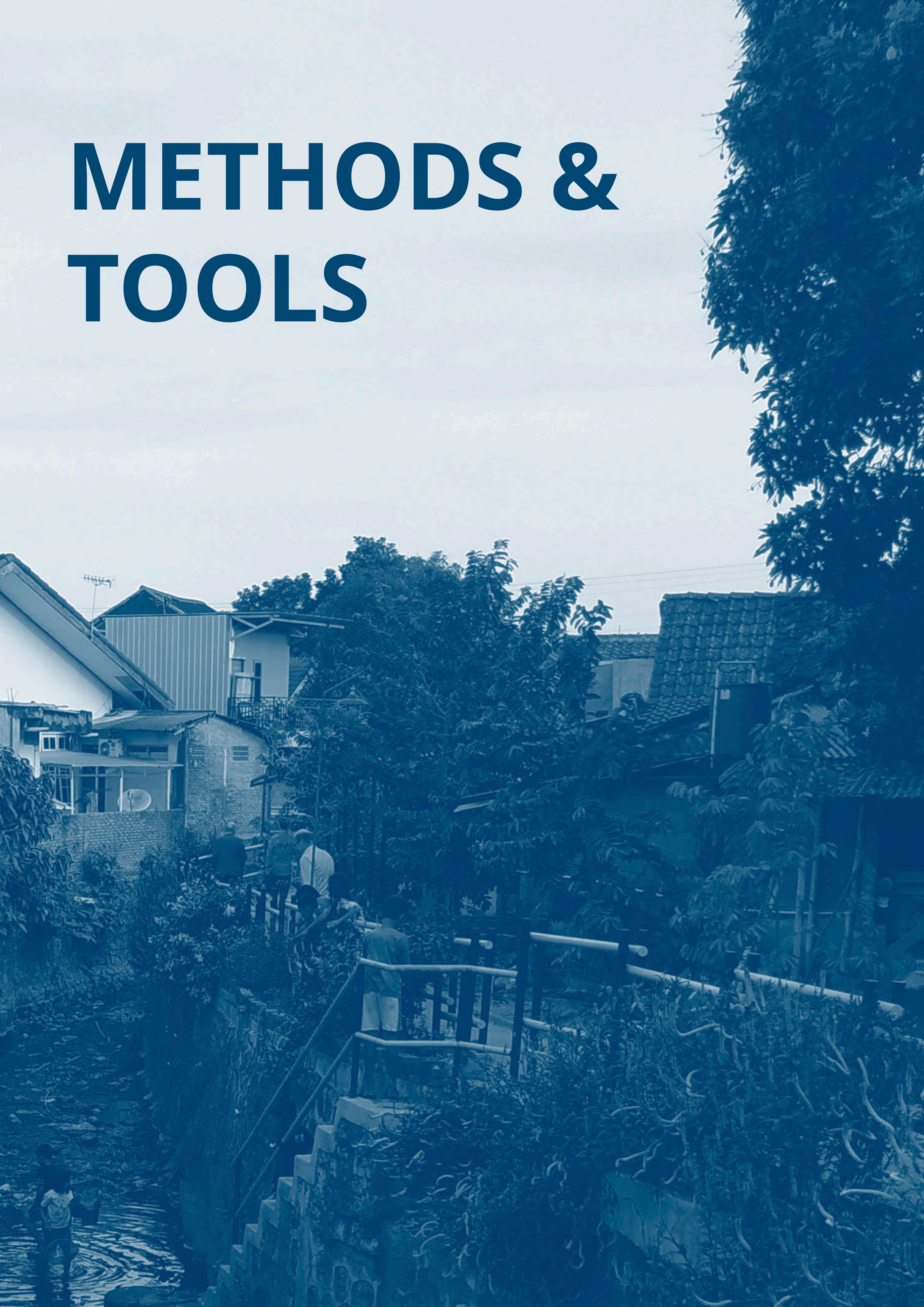
Conclusion

The cultural practices occurred on these two villages show the level of water sensitive communities in preserving and valuing water. While the villages often experience droughts, the cultural practices bring hope, community's engagement towards the environment and balanced principle between nature, human and God. Dandan Kali and Merti Kali Kuning rituals are deeply rooted to the cultural and local beliefs which benefit the ecosystem services at large. The interaction between the community and rivers is ancient, reciprocal, and dynamic. Throughout the time, these interactions were critical for social transformation in the villages. Gaining the understanding of the interaction between environmental spaces and cultural practices provides useful insight in improving current and future rivers in Sleman. The ritual practices can play a major role in restoring the cultural ecosystem services.

1 *Badan Pusat Statistik, 2021*
2 *Hasanudin, 2018*
3 *Lauermann, 2018*
4 *Firman, 2017*
5 *Altshuler, A. A., & Luberoff, 2003*
6 *Sklair, 2017*
7 *Flyvbjerg, 2014*
8 *Subkhi & Mardiansjah, 2019*
9 *Chan & Satterfield, 2018; López de la Lama et al., 2021*

Source: PUW field trip, Sleman, Indonesia, 2022

METHODS & TOOLS



Laura Dissel, Stefanie Knauß, Quirin Luppa, Laila Wendel

Rapid Assessment of Nature-Based Solutions for Water Management

Proposal of an evaluation framework for the performance of water-related nature-based solutions in (peri-)urban areas

This framework was developed in the context of a case study in Sam Neua, Laos, a town located in the narrow valley of the Nam Xam River surrounded by hilly forests with steep hills prone to landslides.[1] Current and Future socio-economic drivers and predicted local effects of climate change influence the available water resources. Expected impacts are erosion, water stress on water supply, and natural hazards such as floodings, landslides, and droughts. One type of currently discussed potential solutions to these challenges are NbS.[2] NbS are defined as "actions to protect, conserve, restore, sustainably use and manage [...] ecosystems, which address social, economic and environmental challenges [...] while providing human well–being, ecosystem services and resilience and biodiversity benefits.[3] NbS can contribute to urban water management through a variety of ecosystem services, such as increased infiltration capacity, enhanced evapo–transpiration, rainwater storage or removal of pollutants. Due to their multifunctionality, NbS often provide multiple benefits at once and offer several benefits for the environment, economy, and the well–being of the local society.[4] Hereby, the involvement of citizens and local experts is crucial for identifying benefits as well as potential trade–offs and costs in their implementation and assessment processes.[5] Many NbS for urban water management focus on improving the environmental sustainability of existing greywater infrastructure. However, in many cities in Southeast Asia, coverage of grey infrastructure is only partial, and it is important to consider that NbS approaches developed in European cities cannot simply be transferred to the urban water challenges in Southeas Asia. NbS must be adapted to the regional context e.g., be expanded for conditions of water vulnerability.[6] A framework for a rapid assessment of water–related NbS in (peri–) urban areas in Southeast Asia was developed to be applied at early stage of a project. After identification of potential solutions from existing NbS databases or compendiums (examples: UNaLab, 2019; UNDP Equator Initiative, 2022; Urban GreenUP, 2019), the rapid assessment is recommended to be applied in order to provide a first scanning and inter–comparison of options.

"NBS offer several benefits for the environment, economy, and the well–being of the local society."

Rapid Assessment Framework

Already existing assessment frameworks, such as the global standard for natural–based solutions by IUCN (2020) and the one by the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation[7] are highlighting the importance of a greater clarity regarding the requirements of a successful implementation of NbS projects and provide an overview of already existing approaches as well.[8] The proposed framework is including relevant criteria based on already existing frameworks, with the objective of offering a rapid as-

Table 1: Elements identified in the literature and included in the proposed framework.

Implemented Methodology	References
Identification of regional challenges and main goals	• IHOBE (2017). Nature-based solutions for local climate adaptation in the Basque Country. Methodological guide for their identification and mapping. Donostia/San Sebastián case study. Ihobe, Environmental Management Agency. Ministry of the Environment, Territorial Planning and Housing -Basque Government. Bilbao. • Raymond, C.; Frantzeskaki, N.; Kabisch, N.; Berry, P.; Breil, M. & Nita, M. (2017a). `A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas´. *Environmental Science & Policy* 77, 15–24. DOI: 10.1016/j.envsci.2017.07.008. • Huthoff, F.; ten Brinke, W.; Schielen, R.; Daggenvoorde, R. & Wegman, C. (2018). Evaluating Nature-based Solutions. Best practices, Frameworks and Guidelines.
Development of indicators to enable comparison of NbS regarding the main function	• Arnold Jr., C. & Gibbons, C. (1996). `Impervious Surface Coverage: The Emergence of a Key Environmental Indicator´. Journal of the American Planning Association, 62(2), 243-258. DOI:10.1080/01944369608975688. • Iacob, O.; Rowan, J.; Brown, I. & Ellis, Chris (2014). `Evaluating wider benefits of natural flood management strategies: an ecosystem-based adaptation perspective´. Hydrology Research, 45(6), 774-787. DOI: 10.2166/nh.2014.184. • Liquete, C.; Udias, A.; Conte, G.; Grizzetti, B. & Masi, F. (2016). `Integrated valuation of a naturebased solution for water pollution control´. Highlighting hidden benefits. Ecosystem Services, 22, 392- 401. DOI: 10.1016/j.ecoser.2016.09.011. • IHOBE (2017): Nature-based solutions for local climate adaptation in the Basque Country. Methodological guide for their identification and mapping. Donostia/San Sebastián case study. Ihobe, Environmental Management Agency. Ministry of the Environment, Territorial Planning and Housing -Basque Government. Bilbao. • Raymond, C.; Frantzeskaki, N.; Kabisch, N.; Berry, P.; Breil, M. & Nita, M. (2017a). `A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas´. *Environmental Science & Policy* 77, 15–24. DOI: 10.1016/j.envsci.2017.07.008. • Huthoff, F.; ten Brinke, W.; Schielen, R.; Daggenvoorde, R. & Wegman, C. (2018). Evaluating Nature-based Solutions. Best practices, Frameworks and Guidelines. • CIRIA (2019): *B£ST Guidance – Guidance to assess the benefits of blue and green infrastructure using B£ST*. London, UK: CIRIA. ISBN: 0-86017-934-6 (10)/978-0-86017-934-74 (13).
Analysis of co-benefits (ecological, economic, social)	• Kabisch, N.; Frantzeskaki, N.; Pauleit, S.; Naumann, S.; Davis, McK.; Artmann, M. et al. (2016).'Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action'. E&S, 21(2). DOI: 10.5751/ES-08373-210239. • Bockarjova, M. & Wouter Botzen, W. (2017). Review of Economic Valuation of Nature Based Solutions in Urban Areas. Technical Report. Naturvation Project. • Raymond, C.; Frantzeskaki, N.; Kabisch, N.; Berry, P.; Breil, M. & Nita, M. (2017a). `A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas´. *Environmental Science & Policy* 77, 15–24. DOI: 10.1016/j.envsci.2017.07.008. • Huthoff, F.; ten Brinke, W.; Schielen, R.; Daggenvoorde, R. & Wegman, C. (2018). Evaluating Nature-based Solutions. Best practices, Frameworks and Guidelines. • WWAP (United Nations World Water Assessment Programme)/UN-Water (2018). *The United Nations World Water*

	Development Report 2018: Nature-Based Solutions for Water. Paris, UNESCO. • CIRIA (2019): *B£ST Guidance – Guidance to assess the benefits of blue and green infrastructure using B£ST*. London, UK: CIRIA. ISBN: 0-86017-934-6 (10)/978-0-86017-934-74 (13). • Somarakis, G.; Stagakis, S. & Chrysoulakis, N. (2019). *ThinkNature Nature-Based Solutions Handbook*. ThinkNature project funded by the EU Horizon 2020 research and innovation programme under grant agreement No. 730338. DOI:10.26225/jerv-w202.
Identification of potential trade-offs	• Pataki, D.; Carreiro, M.; Cherrier, J.; Grulke, N.; Jennings, V.; Pincetl, S.; Pouyat, R.; Whitlow, T.H. & Zipperer, W. (2011). \`Coupling biogeochemical cycles in urban environments: Ecosystem services, green solutions, and misconceptions´. *Front. Ecol. Environ*., 9, 27–36. DOI:10.1890/09022. • Brindal, M. & Stringer, R. (2013). \`Water Scarcity and Urban Forests: Science and Public Policy Lessons from a Decade of Drought in Adelaide, Australia´. *Arboriculture & Urban Forestry*, 39(3), 102-108. • Grote, R.; Samson, R.; Alonso, R.; Amorim, J.; Cariñanos, P.; Churkina, G. et al. (2016). \`Functional traits of urban trees: air pollution mitigation potential´. *Front Ecol Environ*, 14(10), 543-550. DOI: 10.1002/fee.1426. • Kabisch, N.; Frantzeskaki, N.; Pauleit, S.; Naumann, S.; Davis, McK.; Artmann, M. et al. (2016).\`Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action´. *E&S,* 21(2). DOI: 10.5751/ES-08373-210239. • Raymond, C.; Frantzeskaki, N.; Kabisch, N.; Berry, P.; Breil, M. & Nita, M. (2017a). \`A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas´. *Environmental Science & Policy* 77, 15–24. DOI: 10.1016/j.envsci.2017.07.008. • Huthoff, F.; ten Brinke, W.; Schielen, R.; Daggenvoorde, R. & Wegman, C. (2018). Evaluating Nature-based Solutions. Best practices, Frameworks and Guidelines.
Analysis of external factors to assess flexibility	• Calliari, E.; Staccione, A. & Mysiak, J. (2019). \`An assessment framework for climate-proof naturebased- solutions´. *Science of The Total Environment* 656, 691-700. DOI: 10.1016/j.scitotenv.2018.11.341. • Cohen-Shacham, E.; Walters, G.; Janzen, C.; Maginnis, S. (2016). *Nature-based solutions to address global societal challenges*. IUCN International Union for Conservation of Nature. • Huthoff, F.; ten Brinke, W.; Schielen, R.; Daggenvoorde, R. & Wegman, C. (2018). Evaluating Nature-based Solutions. Best practices, Frameworks and Guidelines.
Analysis of financial capacity to assess budget and time frame	• Davies, C.; Hansen, R.; Lorance Rall, E. & Pauleit, Stephan (2015). *Green Infrastructure Planning and Implementation- The status of European green space planning and implementation based on an analysis of selected European city-regions*. Green Infrastructure Planning and Implementation. Report 5.1. DOI: 10.13140/RG.2.1.1723.0888. • Kabisch, N.; Frantzeskaki, N.; Pauleit, S.; Naumann, S.; Davis, McK.; Artmann, M. et al. (2016).\`Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action´. *E&S,* 21(2). DOI: 10.5751/ES-08373-210239. • ADB (Asian Development Bank) (2016). *Nature-based solutions for building resilience in towns and cities: Case studies from the Greater Mekong Subregion*. Mandaluyong City, Philippines: Asian Development Bank.
	• IHOBE (2017): Nature-based solutions for local climate adaptation in the Basque Country. Methodological guide for their identification and mapping. Donostia/San Sebastián case study. Ihobe, Environmental Management Agency. Ministry of the Environment, Territorial Planning and Housing -Basque Government. Bilbao.

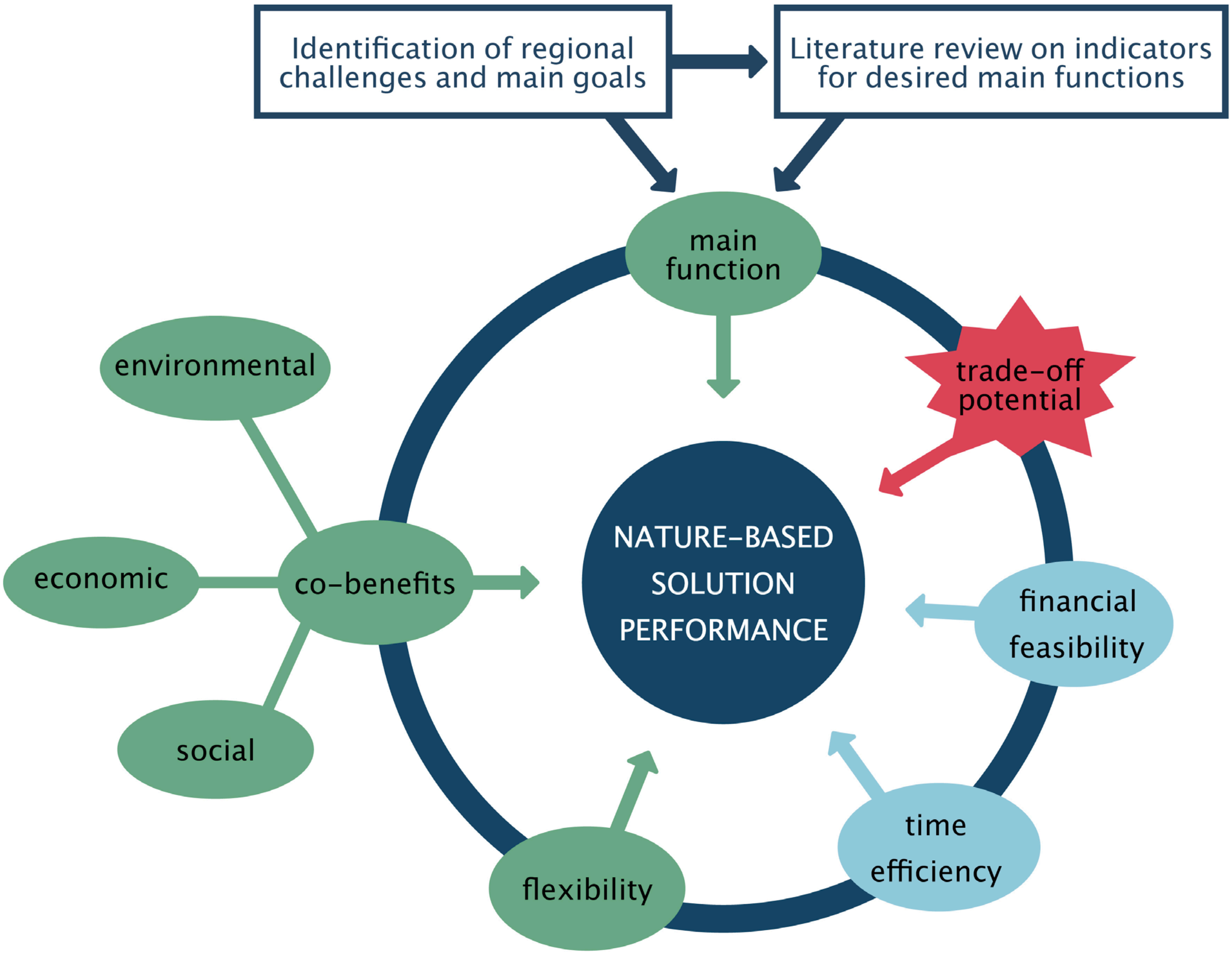


Figure 1: Rapid assessment framework for the overall performance of nature-based solutions. Through literature review (Table 1), relevant elements for the proposed evaluation framework were identified. After identification of regional challenges and local main goals, six criteria of overall NBS performance are assessed: 1) The performance in the main function (the desired main functions derive directly from identified regional main goals. Indicators for this criterion are location-specific and must be identified through literature research); 2) The provision of co-benefits (environmental, social, and economic) by the NBS; 3) Trade-off potential; 4) Financial feasibility; 5) Time efficiency and 6) Flexibility.

sessment of NbS performances with the focus on local challenges, financial feasibility, trade-offs and co-benefits, time efficiency as well as its flexible adaptation towards external challenges and changes.

Due to the multifunctionality of NbS, it is crucial to apply a holistic approach to decision-making processes regarding NbS design, implementation and assessment, and to consider a multi-criteria analysis (MCA) regarding synergies and potential trade-offs.[9] MCA frameworks combine a wide range of information and allow the establishment of preferences between optional solutions in reference to a set of objectives.[10] Within the scope of an MCA, a framework for a rapid assessment of water-related NbS in (peri-)urban areas was developed to support quick decision-making processes through the analysis of a small number of specific indicators. This preliminary comparison of NbS performance can be conducted remotely and does not require large amounts of data, nor high financial inputs. It is designed to be easily understood and applicable among all stakeholders and can be conducted on small scale within local capacities.

For the development of the framework, relevant elements for an assessment of existing and potential NbS were identified through a literature review (see Table 1). Frameworks such as the one developed by the Eklipse expert working group and IHOBE (public environmental management company of the Basque government) point out the importance of the identification of location-specific challenges as well as the development of indicators to enable a comparison of NbSs.[11] Consideration should be given to the relationships between environmental performance, co-benefits for human well-being, trade-offs and synergies, and the potential for public participation.[12] Separating design and implementation processes can enable a more distinct assessment. The inclusion of internal factors (stakeholders) and external factors (future predictions/climatic changes) is essential for both processes.[13] For region-specific decision–making, assessing data availability and conducting an analysis of natural capital enables the analysis of NbS potential regarding local challenges and already existing structures.[14]

Criteria for the assessment of nature-based solutions

The elements identified through literature review (table 1) were combined into an easily replicable evaluation framework consisting of six criteria for the assessment of the overall NbS performance (Figure 1). The criteria are described in–depth in the following section. In table 2, the respective indicators to assess every criterion are listed. As a first step, it is crucial to consider regional challenges and formulate main goals for water–related urban development of the specific case study.

1. Main function: The first criterion represents the main function of the analysed NbS. The selection of this main function is derived from the main goals particular to the area of application. Appropriate qualitative indicators for the location–specific main functions required are defined based on literature review. Representatively, indicators for the three identified main goals related to water management in Sam Neua are introduced: Stormwater Management, River flood protection, Water supply and quality.[15]
2. Co–benefits: NbS can have environmental, economic, and social co–benefits that should be considered when evaluating their overall potential.[16] Environmental co–benefits are additional services for life on earth, e.g., ecosystem services (ES), provided by NbS and can be categorised as provisioning (products derived from ecosystems), regulating (benefits from regulated ecosystem processes), and supporting (maintaining the functionality of all other ES) (Millennium Ecosystem Assessment, 2005). Regarding economic benefits, NbS can have direct and indirect benefits that are often based on long–term developments or expressed qualitatively, rendering a monetary value difficult to determine. For example, water bodies and water sources in urban areas present recreational possibilities for inspirational reasons, tourism, and physical activities and can be utilised as drinking sources. Furthermore, they offer temperature and humidity regulations that mitigate heat island effects, important factors for the micro climate and the promotion of public health.[17] The proposed framework adapts an approach of Hein et al.,(2006) that is used in the NATURVATION project, grouping the economic values of ES according to their utilisation as direct use values, indirect use values, option values, but disregarded non–use values as stakeholder involvement and questionnaires would have been required for evaluation.[18] Social benefits can be associated with improved human well–being and quality of life, thereby enhancing the overall urban living conditions. Factors common to the social co–benefits of NbS assessed in this framework are recreation, social cohesion, and aesthetic values.
3. Trade–offs: : NbS are not only providing benefits but can also have negative impacts or opportunity costs that are often not considered in frameworks solely focusing on positive aspects.[19] A typical trade–off of NbS for water management is the need of space to reduce runoff. This need is competing with other urban needs or the maintenance of urban green spaces that might require irrigation and, therefore, add pressure on water availability.[20] Additionally, risks such as the potential conveying of pollutants from runoff water into ground water through NbS enhancing infiltration or the potential damage to urban infrastructure through drought resistant plant species with aggressive root systems need to be considered.[21] Another group of potential trade–offs of NbS are ecosystem–disservices such as allergens produced by urban trees effecting the public well–being.[22] In the social sphere, potential trade–offs include social inequality.[23] Yet, a complex social analysis is not within the scope of a rapid assessment and is therefore not included in the proposed framework.
4. Financial feasibility: Factors such as the technical, infrastructural, and financial capacity determine the feasibility of a NbS and are crucial for budget estimates.[24] For the rapid assessment, a broad budget categorisation was considered due to limited data availability. Investment costs depend on the availability of technologies, required material and the expertise needed for the implementation.[25] The costs for the implementation can be reduced if the NbS is built upon already existing green structures due to less technologies and implementation time required.[26] In addi-

Table 2: Criteria and indicators. Summarising overview of criteria and respective indicators for the assessment of NBS performance

1. Main function
Stormwater protection ▪ Does the NbS provide temporary water storage? ▪ Does the NbS represent an unsealed surface? ▪ Does the NbS enhance evapotranspiration?
OR **Flood protection** ▪ Does the NbS have the potential to reduce the number of river flooding events? ▪ Does the NbS have the potential to reduce the intensity of river flooding events? ▪ Does the NbS have the potential to reduce the river velocity?
OR **Water quality & supply** ▪ Does the NbS provide water storage? ▪ Does the NbS present an unsealed surface? ▪ Does NbS provide alternatives to groundwater as water resources?
2.a Environmental co-benefits
Does the NbS provide any regulating ES? ▪ Does the NbS provide any supporting ES? ▪ Does the NbS provide any provisioning ES?
2.b Economic co-benefits
Does the NbS provide a direct monetary value? ▪ Does the NbS create an indirect positive impact leading to economic benefit? ▪ Does the NbS represent an investment that, in addition to the main function, reduces risks and increases its future?
2.c Social co-benefits
▪ Is the NbS expected to improve facilities or opportunities for recreation? ▪ Could the NbS lead to more social interaction? ▪ Is the NbS providing a green/natural aesthetical value in comparison to grey solutions?
3. Trade-off potential
▪ After implementation, the NbS does not cause excessive damage to existent grey infrastructure. ▪ The NbS does not cause additional harm to the population through allergies or diseases (with regard to the existing reference situation). ▪ The NbS does not cause pollution or excessively increase urban water demand.
4. Financial feasibility
▪ Is the technological equipment and expertise available? ▪ The NbS does not require high labour input (incl. installation, maintenance and operation). ▪ The NbS does not require the removal of existing structures.
5. Time efficiency
▪ Construction time of the NbS is not excessively longer than a comparable grey infrastructure measure. ▪ NbS provides co-benefits within one year. ▪ Is the NbS effective without time limitation and throughout all seasons?
6. Flexibility
▪ Is there a potential to combine or to adapt other NbS into the design and increase the number of co-benefits? ▪ The NbS is not sensitive against changes of climate. ▪ Does the NbS sustain its (monetary and functional) value with ongoing densification of settlements, population growth and fragmentation?

tion to the costs of implementation of an NbS, necessary maintenance is another key factor for the budget estimation. The maintenance of an NbS requires long–term planning, financing, and responsibility for required duties.[27]

5. Time efficiency: Only a few frameworks assess the values of the benefits measured within a time scale.[28] Since the benefits of an NbS increase most likely in the long–run, there is the need to monitor and evaluate the performances of NbS further than their implementation.[29] For the comparison of NbS performances and decisions depending on local needs, it can be useful to include not only the time of implementation but to include considerations of when and under what circumstances the NbS will be effective.[30]

6. Flexibility: The assessment evaluates how useful the NbS will be in the long–term perspective and if it is flexible to adapt to new challenges and increasing pressures such as rapid urbanisation and climate change. This is particularly important in SEA where NbS are often considered as an alternative solution to grey infrastructure in rapidly changing urban environments.[31] The proposed framework evaluates the flexibility of an NbS based on the parametre 'long–term stability' from the IUCN framework: an NbS that has the capacity to self–sustain over time while accumulating greater value for the society, e.g., through potential combination with other NbS or resilience against climate change and urbanisation, is considered flexible.[32]

Scoring

The six main criteria are assessed in a qualitative way. As proposed by Huthoff et al.,(2018), qualitative indicators for a rapid assessment were designed using the identified relevant elements for the evaluation of the overall NbS performance. One of three qualitative scores is assigned to the qualitative indicators of each criterion:

V – Yes, indicator is met = score +1
X – No, indicator is not met = score –1
N – unclear/No data = score 0

The scores –1, 0 or +1 are assigned to each of the indicators and then added to a total score for each of the 6 criteria (within the range –3 and +3) to evaluate whether the specific criteria are met by the NbS. This results in 6 scores for each NbS and allow the comparison of the strengths and weaknesses of each NbS. Adding these 6 criteria scores to an overall score for the NbS (within the range –24 and +24) allows an overall comparison of NbS performances.[33] The results of such as rapid assessment can be presented and visualised via a radar chart, which is summarising the performance of the evaluated NbS.

Conclusion and Outlook

The framework was applied for the assessment of several NbS in Sam Neua to identify strengths and weaknesses of the developed assessment methodology. The limited scope of the assessment framework and its qualitative character prohibits the inclusion of some indicators crucial for a highly accurate NbS evaluation. The inclusion of external factors into which certain NbSs are embedded is crucial for identifying existing social inequality and possible impacts on such caused by the NbS implementation. Next to social inequality, social participation, and the inclusion of stakeholders into the decision, implementation, and maintenance processes of NbS are indicators of social justice. Past projects of the ADB in Lao PDR showed that the inclusion of stakeholders into the coordination and communication of urban management is crucial to prohibit different perceptions and appreciation as well as to increase local participation and independence.[34] Additionally, to the recommendation of including further quantitative and qualitative indicators, it must be emphasised that this framework is only one part of an NbS evaluation: including a stakeholder analysis and an environmental impact assessment (EIA) would offer a holistic tripartite assessment framework benefiting the holistic urban planning approach of any given project.[35] Despite these limitations, the developed framework offers a fast and straightforward manual and can be considered as a step towards developing a thorough NbS assessment. The framework is recommended for a pre–selection of different types of NbS prior to conducting a more thorough assessment before implementation.

1 ADB, 2018
2 ADB, 2018; Voßeler, 2019
3 UNEP, 2022
4 Raymond et al., 2017a
5 Raymond et al., 2017b
6 Kooy et al., 2020; Bai, 2018
7 Veerkamp et al., 2021
8 Calliari et al., 2019
9 Raymond et al., 2017b; Calliari et al., 2019
10 Hajkowicz et al., 2006
11 Raymond et al., 2017a; Huthoff et al., 2018; IHOBE, 2017
12 Raymond et al., 2017a; Huthoff et al., 2018; Kabisch et al., 2016
13 Huthoff et al., 2018
14 IHOBE, 2017
15 Hodgson, 2019
16 Raymond, 2017b
17 Haines–Young and Potschin, 2018
18 Bockarjova and Botzen, 2017
19 Raymond et al., 2017b
20 reviewed in Raymond et al., 2017a
21 Brindal and Stringer, 2013; Raymond et al., 2017a
22 Grote et al., 2016
23 Bockarjova and Botzen, 2017; Haase, 2017
24 ADB, 2016
25 ADB, 2016
26 Somarakis et al., 2019
27 Kabisch et al., 2016
28 Trémolet et al., 2019
29 Davies et al., 2015
30 Huthoff et al., 2018
31 Bai, 2018; Cohen–Shacham et al., 2016; Calliari et al., 2019; Furlong and Kooy, 2017
32 Cohen–Shacham et al., 2016; Calliari et al., 2019
33 Huthoff et al., 2017
34 ADB, 2015
35 Naumann et al., 2014; Huthoff et al., 2018; Albert et al., 2019

Christian Günner, Sonja Schlipf, Antje Stokman

Challenges and Future Perspectives of a Water–Wise Urban and Neighbourhood Development

Hamburg will only achieve the transformation to blue–green urban water management if all urban development processes consequently address the changing requirements of urban water management right from the very beginning. In order to achieve this, water management, open space, urban development, transport planning and other relevant fields must collaborate from the start.[1] The exchange of urban stakeholders must be supported by good public communication and public participation. In Hamburg, integrated storm water management is seen as a collaborative local task for these groups. In this respect, HAMBURG WASSER and the Authority for the Environment, Climate, Energy and Agriculture (BUKEA) are implementing the RISA Structure Plan 2030[2] concepts and solutions for a sustainable management of storm water in Hamburg within the framework of the RainwaterInfraStrutureAdaptation (RISA) since 2015. The goal is to bundle resources across institutions, to develop unconventional approaches to new challenges in stormwater management, and to implement and realise them.

The following examples show components for urban water management of the future. They are based on lessons learned from projects that have been realised so far, as well as on the need to increase the resilience of urban water management. That means, on the one hand, preserving and precautionary strategies are needed to ensure the robustness of urban water management by qualifying the existing central drainage and purification systems. On the other hand, buffering strategies are also necessary that allow urban water management to become more flexible by integrating modular, redundant and decentralised elements. Furthermore, rapid transformation in the sense of resilience is only possible if creative solutions can be accomplished with a high level of innovation and cooperation.

"Rapid transformation in the sense of resilience is only possible if creative solutions can be accomplished with a high level of innovation and cooperation."

1.0 Precaution

In terms of precaution, benchmark values and framework conditions must be determined that can guarantee the stability of a system. Data and information record the bearing capacity and vulnerability of the drainage system. This provides us comprehensive maps, such as the storm water map published 2021. The citywide monitoring network belonging to HAMBURG WASSER can map precipitation events and show long–term trends. These are visible to the public in the form of the Hamburg Storm Water Index.[3] The rain–fall report published at the beginning of December 2021 summarises the development of pre–cipitation in Hamburg for the hydrological year 2021. In the future, it will be published annually to demonstrate, for example, changes in the annual rainfall pattern.[4] For this purpose, rain recorder and radar data are evaluated and linked with the data of the meteorological service of Germany. Based on these data, precautionary actions can be planned more effectively. For example, it will be possible to identify and evaluate isolated heavy rainfall events more easily. The construction of extensive discharge systems to protect Hamburg's water bodies from the overflow of combined sewer overflows has already significantly improved the performance of the existing combined sewer system in the past decades. Thus, the overflow of mixed wastewater into sensitive waters has been reduced sufficiently. For this purpose, HAMBURG WASSER has extended the former sewer system by additional transport collectors and underground retention basins and has optimised the treatment plant capacities accordingly. For the area of combined sewage disposal, a very high and very good level has thus been achieved.

1.1 Buffering

In the future, the aim will also be to buffer extreme events such as drought and heavy rainfall. This is only possible on the surface and barely any longer underground. A multitude of decentralised interventions at several locations in the city will have to slow down, detain, infiltrate and evaporate the rainwater runoff. This reduces flooding and damage and ultimately reduces the load on collectors and sewage treatment plants from unnecessary rainwater volumes. At the same time, the local water balance is reinforced and the required water supply for vegetation is increased, such as in times of increasing heat and long periods of drought.

One goal of RISA is to harmonize the urban water cycle with the natural water balance. This puts the focus on the management of urban surface water runoff. The closures of local, decentralised water cycles, the construction of near–natural stormwater treatment facilities (e.g., retention soil filters), the disconnection to the sewer system and multiple use of areas that can also be used for other purposes complete the existing, historically grown, underground wastewater system. Green roofs enhance biodiversity and the well–being of the city's population. They can contribute to cooling and – as far as they are designed for it – retain rainwater. The Hamburg Water Cycle approach, which was implemented for the first time in a housing complex in Jenfelder Au, also pursues the goal of closing local water cycles in the context of residential development, i.e., using rainwater, reusing greywater and wastewater and the constituents extracted from it.

Figure 1:
The path to blue–gren (rain) water management
Source: Hamburg Wasser

Figure 2:
Source: Hamburg Wasser

1.2 Rapid transformation

In the long term, the transformation to a Sponge City is only possible as a cooperation of all stakeholders, both public and private. This includes the development and promotion of best practice examples for water–wise mixed use. For example, HAMBURG WASSER together with the FHH's department for the construction of sports facilities, has built a rainwater retention plant under a local stadium. A new joint RISA management unit of HAMBURG WASSER and the BUKEA is responsible over the coming years to promote the RISA strategy[5] in Hamburg. The most important step in this regard is to translate the previous pilot projects and individual processes into acknowledged, applied processes that are binding for all stakeholders in the FHH. Therefore, Hamburg is striving to map and implement the citywide transformation and integration of a blue–green–grey rain infrastructure in newly established, permanent administrative line structures of the FHH. This means not only adapting applicable legal norms in the medium term, elaborating and supplementing funding frameworks, and revising task and responsibility arrangements within the municipal water administration, but also continuing to participate in research projects and implementing innovative projects. Both the internal, interdepartmental cooperation of HAMBURG WASSER and the BUKEA, as well as the participation of other departments of the FHH, the Hamburg districts, the universities, and the social groups ultimately provide the basis for a feasible transformation process of the city.

2. Outlook

In the course of establishing a city–wide blue–green infrastructure and transforming Hamburg into a sponge city, it will be necessary to make substantial adjustments and enhancements to the storm water system. In the future, the city will not only drain and treat sewage and storm water, it will also manage it on site. In addition, sustainable concepts and technologies need to be developed to provide sufficient water resources to irrigate urban landscapes during extended periods of drought, to reduce the increasing demands on drinking water and groundwater resources. Decentralised stored rainwater, but also treated greywater or drainage water can be supply sources for landscape irrigation. In the future, it probably will not be possible to meet all water needs of citizens, commerce, or industry from drinking water, which itself comes from more limited aquifers. This has a direct impact on urban design and planning processes, and requires earlier and more intensive coordination of urban development with stakeholders in the water sector and the public services sector in general. In order to do so, it is necessary to give more consideration to the requirements of the urban water balance in urban development projects in order to make neighbourhoods more resilient, flexible and adaptive and to exploit synergies at the funding and quality scale. This can create value in urban design while also improving climate comfort and the urban water balance.

The RISA–based climate adaptation pathway in the Climate Plan is another step for the City of Hamburg to establish a blue–

Figure 3:
Source: Hamburg Wasser

green urban water management.[6] Merely this political statement from the FHH has lent the process the necessary stimulus to transform the development of a blue–green infrastructure with RISA into a more permanent mission. In addition to the previous RISA aspects of excessive water (heavy rainfall), the climate plan also addresses the aspects of the lack of water and the increasing heat in the city, which poses a risk to health. The catastrophic events in 2021 in North Rhine–Westphalia and other places in Germany have also had an effect on Hamburg's politicians and citizens, who are now paying more attention to the effects of extreme weather events. As a result of it, more information and exchange on the possibilities of water–conscious urban development, but also political targets are desired. In order to implement RISA across Hamburg, it is becoming increasingly important to define the necessary processes to establish a blue–green infrastructure and to translate them into modified rules and tasks. In this context, HAMBURG WASSER plays an important role, influencing this process from the very beginning and is willing to play an active role as a partner of the city in the future. All stakeholders involved have a learning process ahead, and experts face significant convincing efforts to achieve the speed of action required. A key to this is more rigorous and simpler management structures in Hamburg's administration of water resources and more cooperation with urban developers and landscape planners. If not yet existent, it is necessary to create governance, additional financing and operating structures, and to simplify or bundle historically evolved structures in some cases. The inevitable need to adapt to climate change also leaves Hamburg no time for any further adjustments.

1 *Schlipf & Günner, 2021*
2 *Risa, 2015*
3 *Schmitt et al., 2018; https://sri.hamburgwasser.de/*
4 *Hamburg Wasser, 2021*
5 *Risa, 2015*
6 *Bürgerschaft der freien und Hansestadt Hamburg, 2019*

Rossana Poblet, Alexandra Rospigliosi, Rosa Miglio

Implementing Water-Sensitive Urban Design and Green Infrastructures in the Peruvian context

Lima Ecological Infrastructure Strategy (LEIS)

Due to limited water resources in Metropolitan Lima, and inefficiency of the current water system, a new approach to integrative planning is needed. This includes new planning and design tools to establish a functional spatial framework to link urban development with the consideration of optimised water use and reuse. Building upon the existing scientific and practical knowledge of water sensitive urban design (WSUD) and Green Infrastructure (GI) concepts, adapted to the arid climate conditions, the Lima Ecological Infrastructure Strategy (LEIS) has been developed.

Context

The Peruvian capital, Metropolitan Lima, has over 10 million inhabitants. It is located in a desert region of the Pacific coast and is characterised by inequalities in access to basic services, such as drinking water and wastewater treatment, as well as access to healthy green areas. Many public and private green areas, including parks and agricultural land, are irrigated either with scarce potable water or polluted water, while the reuse of wastewater remains low. Therefore, the Lima Ecological Infrastructure Strategy (LEIS) aims to integrate people, landscapes, urban planning and design and water management, to support the urban water cycle and consequently, people's processes. LEIS was developed between 2011 and 2014 within the Lima Water (LiWa) research project "Sustainable water and wastewater management of urban growth centres coping with climate change". Different interventions at all scales have been co–designed and implemented. Among those, the LEIS strategy co–developed the LEIS Principles, Tools and Manual and supported water sensitive urban planning and design strategies for dry contexts. Likewise, Hydro Urban Units (HUU) were defined at metropolitan level and the Lower Chillon River Watershed (LCHRW), located in the San Martin de Porres district, was chosen as study area to develop the Ecological Infrastructure Framework for the Lower Chillon River Watershed. Different projects like the Chillon River Park were conceptualised. In addition, the "Wastewater Treatment Park – Children's Park", was built and inaugurated in 2014, as the LiWa–LEIS Pilot Project aiming to support rural and urban communities, their open–space activities, and environments, including cultural, ecological, and historical landscapes through strategic recovery of the Chuquitanta irrigation canals system used to irrigate agricultural land and urban parks in the periurban area.

Description

LEIS is a coherent strategy aiming to make visible Urban–Rural Linkages within the Metropolitan area of Lima and understand ancient strategies to rurbanise green recreative and productive landscapes and protect food–security in peri–urban areas through integrative strategies. At the same time, LEIS explains the relevance of nature-based solutions for the treatment, use and reuse of wastewater to increase access to green public spaces and ecosystem services in the city, considering integrative aspects.

The LEIS methodology considers a multiscale and multidisciplinary approach considering the LiWa results at watershed level, and integrating them at metropolitan, meso and micro scales.

Between 2011 and 2012, the LEIS Principles were defined as a set of rules for water sensitive urban development based on a multifunctional open space system that contributes to the urban water cycle. These were developed through a participatory process as part of the Lima Concerted Regional Development Plan – Lima 2025 strategy.

Figure 1:
LEIS multiscale and multidisciplinary integrative approach
Source: LiWa Project, http://www.lima–water.de/en/pp7.html

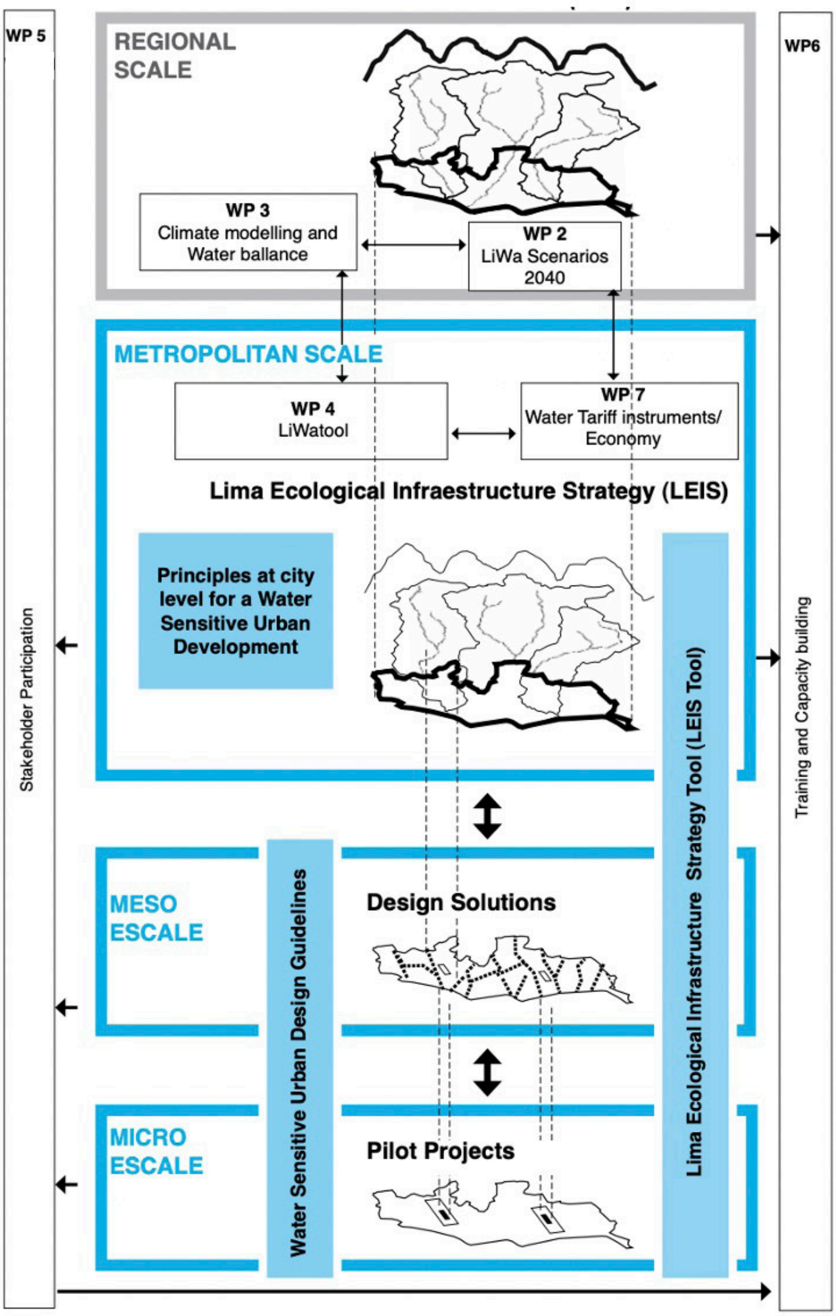
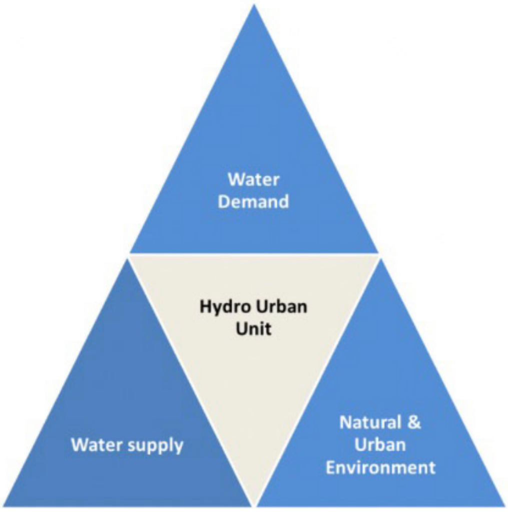


Figure 2:
Participatory process for developing the LEIS Principles
Source: LEIS Book, Eisenberg et al., 2013

Different workshops with key actors were held with the aim of identifying WHAT principles could respond to the different negative processes occurring in the metropolitan area related to landscape and urban development, as well as water and wastewater management.
In the course of that process, five principles were defined:

LEIS P1-PROTECT ECOSYSTEMS AND INCREASE ECOSYSTEM SERVICES	Protect ecosystems and develop multifunctional open space system as Ecological Infrastructure considering availability and integral management of water resources
LEIS P2-PRESERVE AGRICULTURAL LAND	Protect and preserve agricultural land and add value to transform it as urban agriculture improving ecosystem performance, water infiltration and aquifers recharge
LEIS P3-REDUCE VULNERABILITY & INCREASE RESILIENCE	Transform high-risk areas as part of the EI framework, considering a sustainable and resilient approach
LEIS P4-SUPPORT THE HYDROLOGICAL & URBAN WATER CYCLE	Promote water sensitive urban development and design that considers urban water harvesting, saving, treatment and reuse in existing open space in the urban structure, increasing green areas and ecosystem services provision in the city
LEIS P5-STRENGTH EFFECTIVE GOVERNANCE	Effective city governance and management, including integral city vision for water sensitive urban development which is multidisciplinary, coordinated, and inclusive and which involves sustainable landscape planning and design approaches in order to develop resilience to climate change

Figure 3: Combination of relevant characteristics in hydro urban unit Source: LEIS Book, Eisenberg et al., 2013



After defining the principles, the identification of WHERE to develop the ecological infrastructure was carried out. Therefore, the LEIS–Tool serves as a GIS–based planning and quantification tool, which supports the establishment of the layout and assessment functions of the ecological infrastructure as described in the LEIS–principles. It estimates water–related impacts of urban growth and quantifies assumptions on water demand and water re–use potentials of design solution test cases.
The third main output is the **LEIS–Manual**, which is a conceptual design tool with a set of water sensitive urban design measures guiding the design process of green areas towards development of Water-Sensitive green spaces. Different pilots were conducted considering the WSUD guidelines for dry context and 3 summer schools implemented participative temporary solutions. In addition, the conceptual design of the Chillon River Park was elaborated by ILPÖE and approved by the relevant authorities but not implemented. Finally in 2013, the Future Megacities Programme supported the implementation of the LiWa Pilot Project consisting in the design and construction of the Wastewater treatment Park "Children's Park" in La Florida II, Chuquitanta, San Martin de Porres, Lima.

The Wastewater Treatment Park: "Children's Park"
In the framework of the Lima Ecological Infrastructure Strategy (LEIS), and in line with its objectives, a pilot project focusing on the design and construction of a multifunctional open space system, was conceptualised and built. This includes the design of a recreational park for dry context, which is also a wastewater treatment plant irrigating green areas. Nature-based solutions were considered with the installation of a constructed wetland for the treatment of contaminated water for reuse in the irrigation of green areas of this park and a larger park located 300m away.
The area selected for the installation of this pilot project was La Florida II, Chuquitanta, San Martin de Porres in Lima North. It was co–designed and built between July 2013 and August 2014. The main problem in this community is the scarcity of clean water, which is why the community's green areas, cultivation areas and recreational zones, are irrigated with polluted wastewater transported by irrigation channels from the Chillón River. This is the nearest and only available water source. This is due to the fact that the option of buying treated water meant that this would incur additional costs that would difficult for the

left, Figure 4:
View of area before the project showing irrigation channel and vacant land
Source: Rossana Poblet, LEIS–LiWa Team, 2014

Figure 5:
Panoramic view of the project showing treatment system: constructed wetland and reservoir, productive green recreational area, and dry park and playground
Source: Evelyn Merino Reyna, 2014

community and the authorities to assume. The initiative consisted in solving different problems:

- Recover an abandoned former green area decertified by construction of a concrete irrigation channel along the canal San Jose.
- Co–design and build a park in a periurban area, in process of formalisation, and lacking drinking water and green–open spaces.
- Support children's psychomotor development through the design and construction of a green–recreational area dedicated to children under 10 years old.
- Increase green areas and reduce desertification, supporting the urban water cycle and climate variability.
- Develop an easy–to–operate and maintain water treatment system, in such a way that can be operated by the community.
- Consider local cultures and integrate in the design considerations like climate, indigenous vegetation for dry climate and.

Nature-based solutions: Constructed wetland

The treatment system consisted of a grille as pre–treatment, a sedimentation tank for primary treatment, an artificial wetland with vertical sub–surface flow for secondary treatment and a reservoir to store the treated effluent to finally use its effluent to irrigate 598.16 m^2 of green areas.

The system monitoring during its operation, allowed to know its efficiency as a treatment method, its adaptability to the environment, the acceptance of the system and the impacts it generated on the community. This made it possible to evaluate the sustainability as a solution to the problem of water scarcity and quality for the irrigation of green areas.

The treatment system had average efficiencies of over 90% in the removal of pollution, and the water quality values obtained at the exit of the treatment are within the ranges allowed by the Peruvian Maximum Permissible Limits (MPL) for effluents from domestic or municipal wastewater treatment plants and allows for safe reuse according

Figure 6:
Principle of the structure of water treatment in the wetland (Descriptive Memory – Treatment of Canal Water in the Artificial Wetland WTL–Rotaria for the use in irrigation of the park in La Florida II – Chuquitanta, 2014.
Source: Rotaria del Perú, 2013

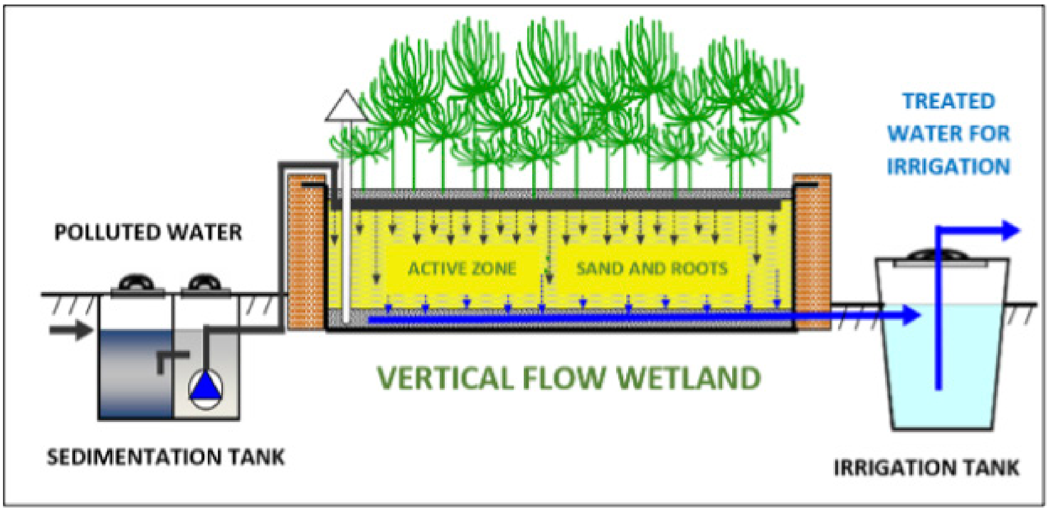


Table 1:
Average results of water quality parametres.
Source: Sostenibilidad de un Humedal Artificial de Flujo Vertical, para el Tratamiento de aguas Contaminadas con fines de reúso, Garcia L., 2021

Water quality parameter	Unit	Results achieved			% Average efficiency
		Inflow to the system	Inflow to the wetland	Outflow from the wetland	
Hydrogen potential (pH)	-	7.69	7.56	7.54	-
Electrical conductivity (E.C.).	uS/cm	656.25	701.5	961.75	-
Turbidity	NTU	433.76	170.41	1.73	100%
Suspended Solids	mg/L	3800	787.5	68.75	98%
Sedimentable Solids	ml/l	0.99	0.13	< 0.01	99%
Biochemical Oxygen Demand (BOD)	mg/L	9.68	5.07	2.08	79%
Faecal Coliforms	NMP/100ml	3807.07		495.06	87%
Parasites	N°/L	116.25		0	100%

to World Health Organisation (WHO) Guidelines (Health guidelines on wastewater use in agriculture and aquaculture)

In the same way, the social evaluation yielded positive results for the adoption of the technology by the community, which is reflected in the predisposition of over the 85% beneficiaries to get involved in the improvement plans, in the adoption of commitments and responsibilities for the operation and maintenance of the treatment system. In addition,100% of stakeholders consider that the park has improved the landscape and the environment in the area. All these excellent results made this project a prototype of an ecological park that could work for small towns with scarce water resources. Additionally, it helped solve water quality problems in the irrigation of green areas in a natural way. It also provided an adequate cost/benefit ratio and consolidated community participation as the key to sustainable sanitation project development.

Challenges and Limitations
The LEIS approach tried to overcome the challenges the project was dealing with in Metropolitan Lima between 2011 and 2014, that are similar to other cities. Among those we could identify:

- Partial overview of the territory as a whole and its open space system at different scales, limit people's current and future development.
- Basic cadastral information from various sources was often at variance. It could be noticed a large divergent spatial information depending on the field of interest, multiple scales, changing resolution and the incompleteness of information.
- Administrative political division force administrative borders onto the city

Figure 7:
LEIS team explaining the park design and the constructed wetland parts and functioning to the San Martin de Porres Major (2011–2014) Mr. Freddy Ternero and La Florida II residents during the WWT Children's Park inauguration, 15 August 2014.
de reúso, Garcia L., 2021
Source: LEIS–LiWa Team, 2014

that are hardly recognisable on the ground but have a deleterious impact on the availability and the harmonisation of information.

- Limited metropolitan and regional planning institutions, and outdated planning instruments at the time of the project. Nevertheless, outdated planning instruments were a challenge and an opportunity to show possibilities of new integrative approaches.
- Historically independent districts, and local municipalities competing with metropolitan entities exacerbate a weak governance.
- Lack of unified view of the city at metropolitan level, integrating the Metropolitan and Regional Lima and the Callao Region and Callao Constitutional Province.
- Strong sectoral organisation of spatial, social and infrastructure issues, exacerbate the "silos" approach, and jeopardize the integrated planning process.
- Disconnection between territorial and urban planners, open space designers and water engineers, made difficult a multidisciplinary approach.
- The administrative entities (districts) are too diverse in terms of different urban conditions to be useful for any city-wide comparison.

Lessons Learnt for the Pilot Project:

- The implementation of integrative projects depends on participative processes and effective support and management of the main stakeholders: Municipalities, Promoters and Users.
- The sustainability of the LiWa pilot project is only guaranteed with the commitment to operation and maintenance of the community and local leaders. In this sense, responsibility can only be transferred through the identification of weaknesses and training of the groups involved.
- Likewise, it is important to generate the appropriate link between government leaders and the user community, thus promoting effective communication and participatory management for the sustainability of the project

The LEIS impact includes

- The LEIS methodology led to the definition of integrative principles, the creation of meso–scale spatial units that define different typologies of urban spaces with relation to the urban water cycle and provided guidance for the integrative planning processes and implementation of demonstration projects, like the WWTP Children's Park showing LEIS's multidisciplinary and multiscale coherence.

- The LEIS–Principles for ecological infrastructure were defined and harmonised with the Concerted Regional Development Plan, developed by the Metropolitan Planning Institute (IMP) in 2012, and official adopted by the Lima Metropolitan Municipality (MML) in 2013. These principles are currently included in the LIMA 2040 PLAN MET (Metropolitan) for sustainable urban development, promoting the implementation of the ecological infrastructure at different scales.
- In order to study possibilities for the application of LEIS and discuss the strategy with local stakeholders, academia and residents, the Lower Chillon River watershed was chosen as the LiWa – LEIS demonstration area. In a feedback loop, the findings from the work in the demonstration area, contributed to shape the LEIS water sensitive urban development and design recommendations
- At meso scale the hydro–urban units allowed to recognise the territory considering water consumption and population growth. That allowed to propose decentralised systems for green areas generation considering treated wastewater.
- On the site level, WSUD guidelines for open space design were developed and included in the LEIS Manual. These included nature–base solutions like constructed wetland. Analyses of several existing open spaces and new design projects has shown how water sources and vegetation are dealt with in the open space design in a sustainable way.
- The WWTP "Children's Park is the WWTP built in an public open space. It demonstrates how nature-based solutions, such as constructed wetlands, for example, can be integrated in public open spaces to treat wastewater, and create green areas and also create.

Figure 8:
Children under 10 years old enjoying recreation of healthy green areas irrigated with clean wastewater treated by constructed wetland
Source: Eva Nemcova, LEIS–LiWa Team, 2014

- The Lima Open Space Plan "Plan de Espacios Abiertos e Infraestructura Ecológica de Lima" (PEAIE), defined in 2013 by the Lima Metropolitan Municipality, was based on the LEIS strategy.

Conclusions

LEIS supported a better understanding of the term "open space" as strategic planning instrument to redirect unsustainable urban development. That allowed the creation of the ecological infrastructure network described as a multifunctional system of open spaces and defined through official ordinance as "ecological structure of Lima". This system will help to tackle urban development challenges in a more efficient and sustainable way, contributing to improvement and protection of the urban water cycle in a participative way.

The LEIS strategy was applied at different scales and working closely with the metropolitan and local district administration, technical agencies, research institutions, civil society and surrounding communities. Results were:

- Active multilevel governance and key actors' groups, to address water, land and open space aspects in an integrative manner.
- The design for the "Lower Chillon Ecological River Park Chuquitanta", as a multifunctional lineal corridor over the river bank that acts as an ecological water treatment facility from various water sources; as flood protection area during rainy season in the upper watershed; and as river park for recreation during dry season. In November 2013 the project "Creation of sport, leisure and cultural services in the Chuquitanta Ecological Park, lower Chillon River Watershed" presented by Park Services of the Metropolitan Lima Municipality (SERPAR) was approved by the Ministry of Economy under the Participatory Budget process.
- The Ecological Infrastructure Landscape Framework Plan for the Lower Chillon River valley with a set of policies and systemic demonstration projects at meso and micro level, integrating natural landscapes, cultural heritage, cultural landscapes and social processes.
- The "Wastewater Treatment Park – Children's Park", located in the San Martin de Porres district, built and inaugurated in 2014 and still operating.

"LEIS supported a better understanding of the term 'open space' as strategic planning instrument to redirect unsustainable urban development."

Lucia Herbeck, Torsten Grothmann, Christof Voßeler, Manfred Born

Living Labs for Heavy Rain and Flood Prevention

Neighbourhood–based participation processes in the project "BREsilient – climate resilient future city Bremen"

Facing an increasing threat of heavy rainfall, floods and storm surges due to climate change, there is a need in the city of Bremen to design adaptation and precautionary measures, especially for unprotected areas. The two neighbourhoods of the living lab 'Flood Risk Prevention Pauliner Marsch/Im Suhrfelde' are located in close proximity to the Weser River and outside of the dyke line that protects most of the city area from flooding. Due to their exposed location, these neighbourhoods will be particularly affected by climate change impacts. Both neighbourhoods are located in the heart of the City of Bremen and are intensively used by sports and allotment garden clubs as well as local recreation areas. A few people also live in the neighbourhoods, which are only protected from flooding to a limited extent by an earth wall and are therefore officially designated as a flood risk area. In the event of a very severe storm surge, these neighbourhoods could be flooded to a height of up to 4 m in extreme cases.

The living lab 'Heavy Rainfall Prevention Blumenthaler Aue' deals with the risk of flood hazard caused by heavy rainfall events in a small catchment area of the Blumenthaler Aue, a 13 km long creek. The buildings of the Blomendal castle complex are located at the confluence of the creeks Blumenthaler Aue and Beckedorfer Beeke in a depression without flood protection facilities at a point with a high risk of flooding within the designated Blumenthaler Aue/Beckedorfer Beeke floodplain. The castle complex is home to a children's day care centre (KiTa) and the archives of the Blumenthal local history society. The castle grounds are regularly used by various associations and for events and celebrations. Additionally, a few houses are located on the edge of the floodplain. Running waters with a small catchment area and a large gradient react sensitively to heavy rainfall events. The resulting flash floods often have a very short warning time – if they can be predicted at all. Since it can be assumed that heavy rain events will occur more frequently and more intensely in the future due to climate change, a specific precautionary concept for this area is of particularly urgent.

The following goals were pursued in the two neighbourhood–based living labs:

– Compilation of background knowledge, the current situation and analysis of flood hazards in the two model areas,
– Collecting and integrating knowledge about the risks of storm surges and heavy rainfall with potential flash floods,
– Creation and increasing risk awareness among participants,
– Encouraging the users of the neighbourhoods (e.g. associations, day care centres, residents or citizens) to take precautions themselves,
– Identification of possible measures for flood prevention in the event of heavy rainfall or storm surge,
– Evaluation and prioritisation of potential adaptation measures,
– Specification of measures for later implementation.

Procedure of the Living Labs

• Situation and hazard analyses

In a first step, the two model areas "Pauliner March/Im Suhrfelde" and "Blumenthaler Aue" were each comprehensively described in a situation analysis. All available data, such as the number and type of buildings and the existing infrastructure, were compiled and visualised in maps. In a stakeholder analysis, affected and relevant persons, associations, authorities and organisations were identified and the requirements for flood prevention and preparedness for heavy rainfall and flash floods were recorded. A hazard analysis was also prepared for both model areas: In the Pauliner Marsch/ Im Suhrfelde area, this was done on the basis of various flood scenarios caused by potential storm surges/inland flooding. In the Blumenthaler Aue area, hydrological analyses of runoffs, taking heavy rainfall and flash flood events into account, were used to investigate how the water bodies react to extreme rainfall events.

- Workshop series

The key element of the two living labs was a two– or three–part workshop series "Pauliner Marsch: Shaping flood prevention together" and "Blumenthaler Aue: Shaping heavy rain prevention together". The workshops were organised by city administration supported by scientific agencies and institutes. The workshops took place on site in the respective areas in 2019 and 2020. Based on the stakeholder analyses, the chairpersons of the affected associations and organisations, the responsible administrative representatives, the heads of the local authorities, the members of the district parliaments and affected citizens were invited to the workshops. The stakeholders were targeted and invited, although the events were basically open to the general public. Registration was possible via the project website. Additionally, most of the events were announced by the local press and the BREsilient newsletter. Between 30 and 50 people participated in each of the three–hour workshops, which included lectures by administrative representatives, technical contributions, small group work, discussions and site visits. The results of the situation and hazard analyses were presented as a basis for the discussion. Moreover, at the Blumenthaler Aue workshops there were short presentations, e.g., on Bremen's heavy rain maps as well as on a heavy rainfall early warning system used in the city of Lübeck. At the Pauliner Marsch/Im Suhrfelde workshops there were presentations on the results of a hydraulic study covering possible property protection measures as well as on reporting chains in the event of a storm surge in the flood prone areas. In thematically divided small working groups, the stakeholders exchanged experiences and developed and discussed possible adaptation measures to reduce the impact of a flood and heavy rain events. The focus was on the possibilities of early notification and behavioural precautions. In the Blumenthaler Aue area, site visits were also undertaken as part of the working group sessions in order to get a picture of the respective situation on site. The measures developed in the working groups were recorded and presented in the plenary session and then evaluated and prioritised by all participants using sticky dots. In this way, the participants came up with concrete measures that were suitable for implementation.

In the model area Pauliner Marsch/Im Suhrfelde, these included in particular:

– Measures to improve the informa-

Figure 1:
Overview on processes in the living lab "Heavy Rainfall Prevention Blumenthaler Aue"
Source: Author

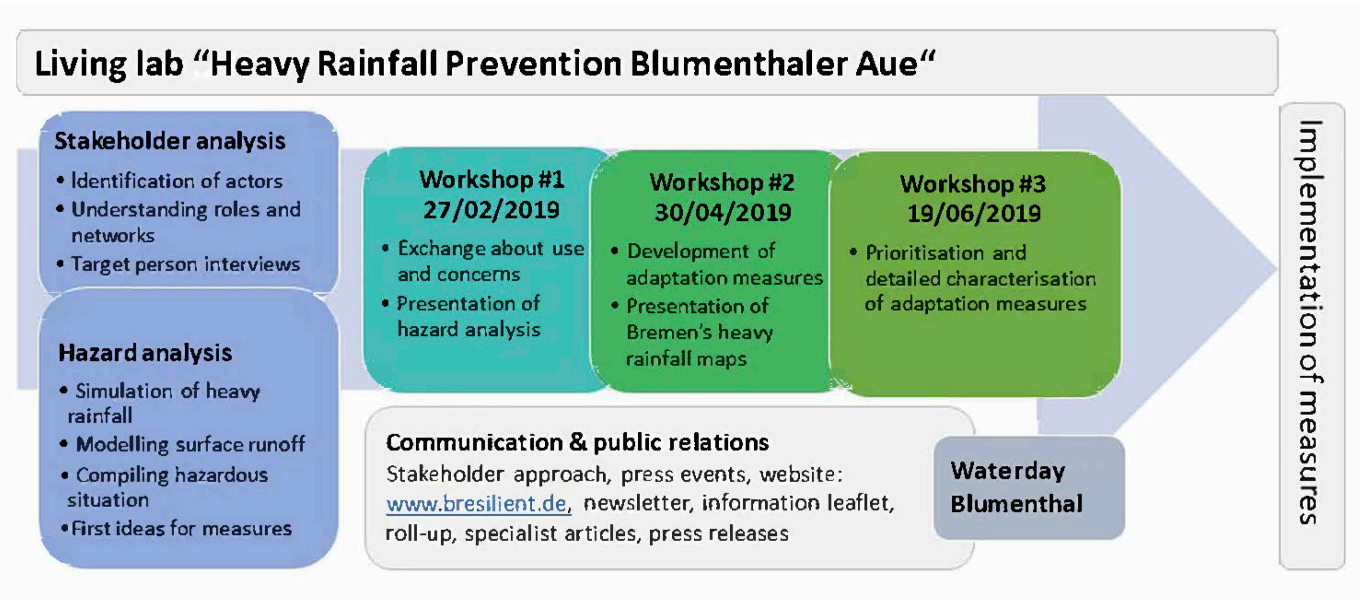


Figure 2:
Pauliner Marsch
Source: Meyerdirks

tion and communication structure: communication of potential hazards as well as advance warning and precautionary measures through information boards and leaflets.

– Advisory measures to strengthen self–protection: In particular, the associations located in the project area expressed a need for concrete advice on flood–adapted structural property protection.

– Infrastructural measures: Improvement of the drainage capacity, e.g., by means of a ditch system, so that in the event of flooding the areas can be drained faster and without damage.

In the Blumenthaler Aue model area, it became clear that technical flood protection by the government to prevent flash floods is not possible. Instead there is an increased need for private self–protection measures. Accordingly, the participants in the workshops primarily formulated the need for improved information and advisory services. The testing and installation of a forecasting system with short–term warnings for heavy rainfall was identified as a suitable precautionary measure.

Figure 3:
Overview on processes in the living lab "Flood Risk Prevention Pauliner Marsch & Im Suhrfelde"
Source: Author

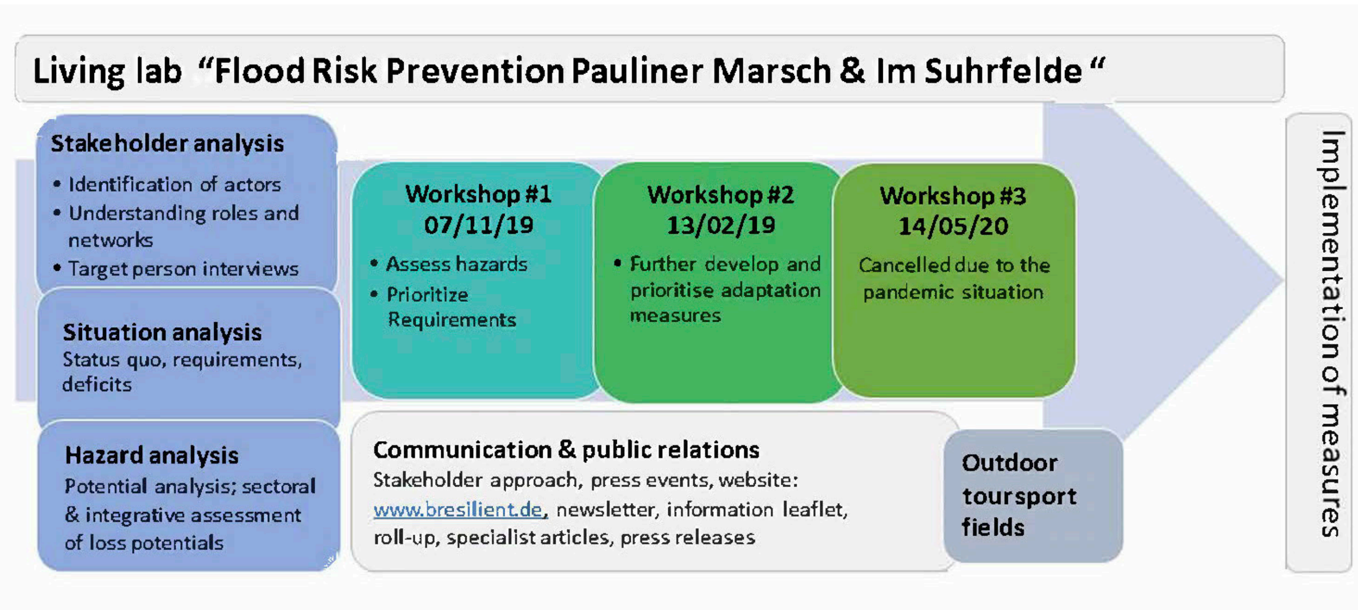


Figure 4:
Pauliner Marsch
Source: ecolo

Both living labs were accompanied by continuous public relations work. At the end of each workshop, the participants were asked to fill in an evaluation questionnaire. Each event was analysed with regard to the quality of the process (e.g. quality of knowledge transfer, opportunities for participation), as well as on the knowledge of risks and precautionary measures and the motivation of the participants to take precautions themselves.

- Further events

In the model area "Blumenthaler Aue", the "Water Day Blumenthal" was established in addition to the workshop series. The Water Day took place within the framework of a traditional flea market held annually on the castle grounds. This enabled a wider circle of people to be reached and informed about the risk situation in the area. At the castle courtyard, visitors could learn about the project results of the workshop series and visit an exhibition on personal precautions. In addition, several local partners gave advice and presented funding opportunities on how to prevent heavy rainfall at home. In the model area "Pauliner Marsch/ Im Suhrfelde" an outdoor walk throughout the sports areas was organised. A technical expert advised the sports clubs on possible economic damage to the sports fields as well as environmental risks in the event of flooding.

Reflection on the process and lessons learned

The participation process made it possible to jointly weigh up and prioritise concrete needs for action and possible adaptation measures. The results of the evaluation questionnaires revealed that risk awareness, knowledge about flood hazards and self–protection measures as well as motivation to take these measures could be increased among the participating actors. Additionally, networking and mutual trust between the participants increased. In this context, it should be particularly emphasised that the workshops succeeded in increasing the belief of the majority of participants that effective measures can be implemented to prevent damage from flooding through joint action by the Bremen administration with the users or residents of the areas at risk. In this way, the perception of flood prevention as a joint responsibility of society as a whole could be promoted. The living labs in the BREsilient project were therefore an important step for raising awareness and further clarifying the flood risk from flash floods and storm surges in the two model areas among the involved stakeholders.

Information offered at the workshops and other events contributed to participants' knowledge gains. For example, support was provided on where to obtain information on storm surge forecasts and how the reporting chains work in the event of a storm surge. Mutual learning between the participating municipal administration representatives (e.g. about the obstacles for citizens at risk to take precautions themselves) and the participating association representatives and citizens (e.g. about the precautionary options of the administration) was successfully promoted. The results of the evaluation questionnaires showed that the increase in knowledge about risks and precautionary measures among the participants was related to the quality of the knowledge transfer. Thus, knowledge transfer that is didactically conducted in a competent and positive way is a factor for success when it comes to increasing knowledge, in living labs as well. Here it is important – as the evaluation results demonstrate – to avoid a dominance of experts in the discussions. This had a clearly negative effect on the knowledge gains of the participants and the integration of knowledge between them. In addition to the knowledge–related effects, the living labs had effects on action, especially on increased motivation for self–precaution. The evaluation results revealed that the more satisfied the participants were with the opportunities to have a say (e.g. on the risk prevention measures to be taken in the respective areas) in the living lab workshops, the greater the increase in their motivation to take self–protective measures. This is closely associated with the quality of the living lab workshops as places for "real participation". Obviously, association representatives and residents who participate in workshops on flood preparedness organised by the municipal administration are more willing to follow suggestions for self–protective measures if (they get the impression that) they have good opportunities to have a say in the workshops and that they can discuss with representatives from the municipal administrations on the same level.

important channel for addressing the residents was activated and actors from local politics could be activated to participate. Through targeted telephone enquiries prior to the workshops, additional actors were persuaded to participate. It proved to be particularly helpful to approach actors who have a multiplier function in their area and could thus contribute to the dissemination of the results. In this way, the results of the BREsilient living labs were also reported in club meetings, such as in allotment and sports clubs, for example. Other important factors for the success of the living labs were practical relevance, as the workshops were organised by the city administration rather than a scientific institute, professional invitation and workshop management, external and neutral moderation, and the selection of an appealing event location directly in the respective project area with provision of catering during the breaks. The key to the long-term success of the participation process and the improvement of the situation in the areas seems to be the rapid implementation of some public sector measures as well as private precautionary measures based on the priorities identified in the workshops. For this purpose, the project funding of a subsequent implementation phase by the

"The participation process made it possible to jointly weigh up and prioritise concrete needs for action and possible adaptation measures."

Conclusions

The evaluation surveys of the living labs indicate that pure information events to promote personal precautions are unlikely to be effective. Rather, private actors, such as representatives of associations and residents, want to discuss and negotiate with governmental actors on an equal footing, in participatory events, why they should do something to prevent flooding and why the responsibility for doing so does not lie with the government alone. Intensive public relations work was useful in attracting participants to the living labs. A large, media–effective kick–off event, postal invitations, a project website, a newsletter and continuous press work proved to be effective. By involving the district parliaments, an

Federal Ministry of Education and Research (BMBF) proved extremely important in order to maintain interest in the project and motivation among the actors to take prevention action. It was already apparent during the participation process in the living labs that without timely action, frustration would spread among those involved. In order to continue the exchange between the stakeholders in the long term, the establishment of a "Blumenthaler Aue heavy rain partnership" and a "Pauliner Marsch/ Im Suhrfelde storm surge partnership" is being initiated in the current implementation phase of the BREsilient project.

Frederic Hebbeker, Uzabi Baidar, Isabelle Knauf, Ololade Shokan

Flood Inundation and Risk Mapping

Conclusions for flood management planning in Kratié, Cambodia

Title:
Kratié Flood 09.08.2018
Source: Khmer Times

Case study and flood management practices in Cambodia

Kratié is located in the Cambodian floodplains along the eastern bank of the Mekong River.

The Mekong River has a length of approximately 4,800 km and a catchment area of 795,000 km^2, extending into most of mainland South–east Asia. The landscape surrounding Kratié is part of the river valley of 12 km width and features only minor elevation changes.[1]

At Kratié the Mekong already contains 91% of its mean streamflow volume when it reaches the city.[2] Significant hydropower development on the Mekong River and tributaries influences the hydrological regimes of the river.[3] This human induced development has changed the natural water regime of the Mekong and provides potential benefits, but also threats to the city.

The occurrences of flood events have been continuously reported and in 2018 affected >9,000 families in Kratié province.[4] As a result, flood events are identified by the local population as a primary water related concern.[5]

Due to the low topography along the river plains and the regional climate, floods are part of the natural water cycle in Kratié and occur during the wet season from May to October.[6] However, dam management practices (releases during the wet season) are also recognised as a cause for floods. Additionally, deficits in the local infrastructure and capacity of responsible authorities fail to adequately reduce the exposure and vulnerability of the local population during flood events.[7] As a result, parts of Kratié experience flood situations lasting between a week and a month, not only because of the rising Mekong River, but also from rapid monsoon rainfalls, which effect the local streams that drain the hinterland of the region.[8] Flood hazard assessment from the Mekong River Commission confirms a hazard from local tributary rivers.[9] The example case of this report is specifically concerned with the Prek Te watershed, that has an area of 4,183 km^2, according to the HydroBASIN database.[10]

The Mekong River Commission maintains a hydrometeorological monitoring Station in the city,

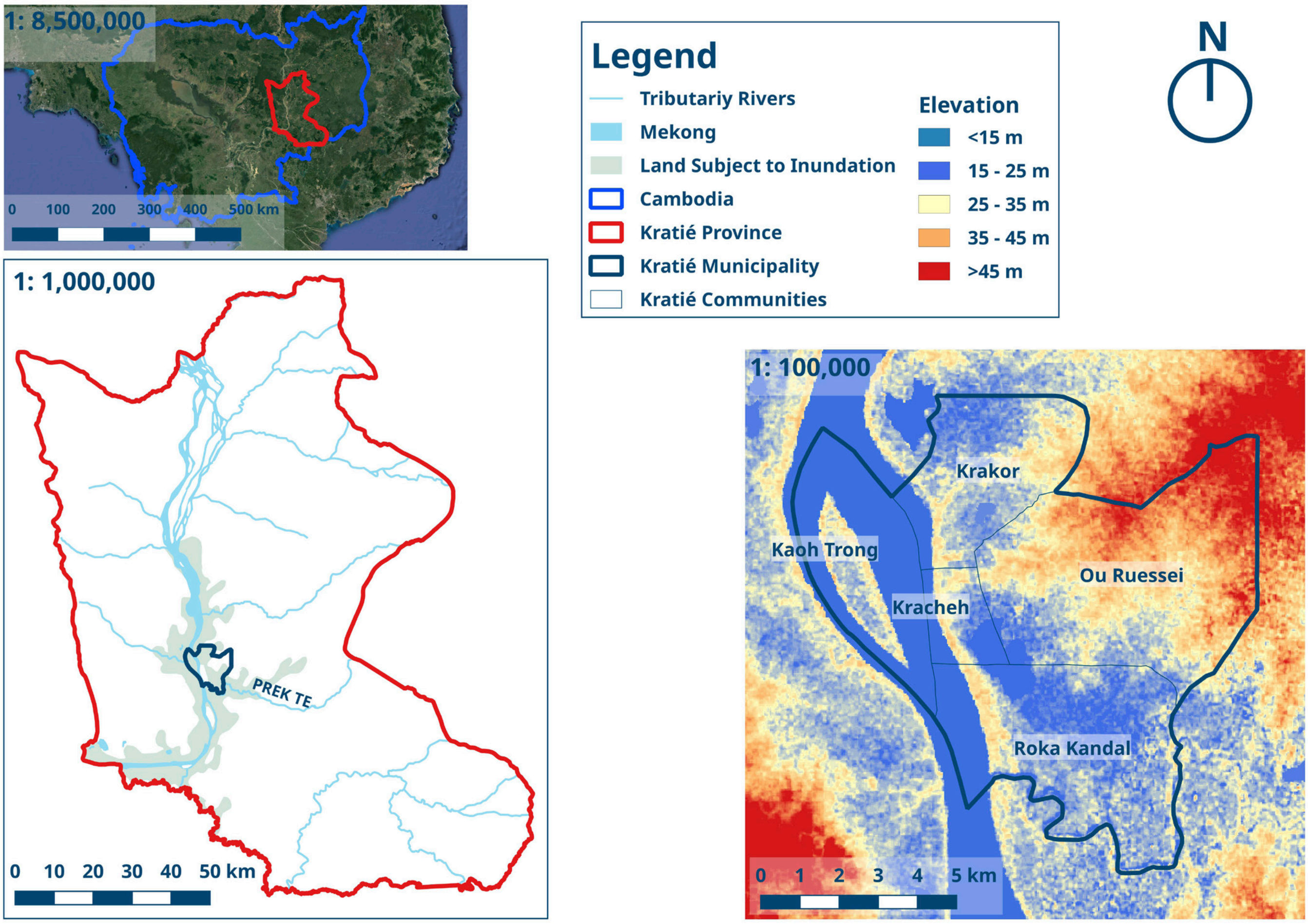


Figure 1:
Map of the study area Kratié, Cambodia
Source: Source: DIVA GIS, SRTM (USGS Earth Explorer) and Google Earth

which reports measurements through their data portal[11] (MRC, n.d.). Reported relevant parametres for flood management include water level (manual & telemetry), precipitation, and discharge.

In Cambodia, hydro-meteorological observations from monitoring stations and one radar system, data management and national forecasts as well as early warning are handled by the Department of Meteorology (DOM) of the Ministry of Water Resources and Meteorology (MOWRAM). The monitoring network within Cambodia includes 50 operating manual and 12 automated stations. Observations are used for flood and weather warnings through mass media for local authorities and other stakeholders that implement emergency preparedness and response, coordinated by the cross ministerial Cambodia National Committee for Disaster Management (NCDM)[12]. According to a 2016 report, a major concern is the protection of important population centres through dikes and other embankments, while local adaptation includes individual building measures like stilt–houses.[13] Flood management aspects are delt with on the regional level by the Mekong River Commission (MRC) through the Regional Flood and Drought Management Centre (RFDMC) in Phnom Penh, which provides flood forecasts and annual reports. Among others
transboundary hazard, damage & risk assessments are conducted.[14]
Furthermore, the commission provides for an overarching strategy within the Flood Management and Mitigation Programmeme. Measures include basin wide Integrated Water Resource Management, data–sharing, planning principles and capacity building.[15] Additionally, technical guidelines are prepared, which include public awareness raising, evacuation planning and emergency management.

In Cambodia, this involves strengthening of embankments, construction and reinforcement of dikes or by–pass channels to improve water drainage systems.[16] In order to enhance flood preparation and warning, the Commission applies a variety of Models.[17] Results and warnings derived from the flood monitoring systems are reported through the MRC website in near–real time.[18] The existing flood management approaches are not comprehensive for district and municipal level, which provides a challenge to adequately address the existing flood hazards.[19] On the local level, flood management practices are not very specific, and in the case of Kratié, the only relevant guideline is the definition of a Flood – and Alarm threshold related to the monitored water level of the Mekong River. An Alarm level is triggered at 22.0 m and a Flood level is reached at a water table of 23.0 m.[20]

Part I: Inundation mapping from Space and potential for flood management

Frederic Hebbeker

State of the art, methodology and application

Remotely sensed data is known to provide significant mapping capabilities and is of important use for flood monitoring, especially in ungauged rivers.[21] Multitemporal satellite images have also proven to be useful for monitoring specific events (Klemas, 2015). Inundation mapping can be carried out using optical (passive) or microwave (active) satellites, but optical sensors are limited by the occurrence of clouds. For optimal flood mapping, one reference image before the event as well as samples taken during and after the flood peak, account for a comprehensive monitoring of a single events.[22] Applicable flood mapping methodologies include the calculation of surface cover indices[23], time series analysis & change detection[24], Elevation based modelling[25], thresholding[26], Random Forest based classifications[27] or flood frequency mapping.[28]

Due to the limited cloud cover penetration of optical sensor products, open–source accessibility as well as spatial and temporal resolution, the Sentinel–1 mission of the European space agency (ESA) provides high potential as remote sensing data source for flood mapping.

Sentinel–1 (microwave sensor) applies SAR technology that can penetrate cloud cover and for flood monitoring utilise the fact that water surfaces absorb radiation signals form the Satellite stronger than other surfaces and appear darker in the image.[29]

The here applied methodology produces binary water/non–water maps, where visual thresholding is applied to a histogram of the returned signal. In a multitemporal comparison, this enables the separation of permanent– and flooded water surfaces. Results can then be validated with optical indicators (NDWI or MNDWI) from Sentinel–2 or Landsat images when available.[30] Examples of binary thresholding include studies from Kiran et al.,(2019), Negula et al.,(2016) & O´Hara et al.,(2019). Furthermore, a very easy to use approach of this procedure is published in the Opensource UN knowledge portal[31] "Step by Step: Recommended Practice Flood Mapping".[32]

Due to the decent spatial (10m) and temporal (6 days) coverage of Sentinel–1, the images can be used to improve knowledge about spatial flood causes.[33] For the comparison of multitemporal images through visual inspection images can be overlayed and compared with historical flood return periods, if available.[34]

Further application includes the establishment of inundation archives as an important source for model validation/calibration and flood risk assessments[35] near–real time flood monitoring for authorities in emergency flood responses coordination[36] or as an operational tool to decide on effective measures and policies to prevent or mitigate flood impacts.[37] Previous research has concluded that Sentinel–1 imagery can provide high accuracy and fast information delivery after acquisition, through automated processing chains and web–based dissemination.[38]

For this study, spatial flood inundation mapping around Kratié and parts of the adjoining Prek Te watershed are conducted on the basis of eleven Sentinel–1 images from 2018. The data is then interpreted to derive potential suggestions on the current flood management practices and dynamics to identify the influence of the local Prek–Te subbasin through rapid monsoon precipitation and the rising of the Mekong water table with potential backflow into riparian landscapes.[39] The main questions to be answered are:

1. Which areas flood, and when?
2. How does the amount of inundated surface correspond to the water table of the rise/fall of the Mekong River?

In order to determine an applicable point in time for the analysis, data from the Kratié station (Code: 014901) were reviewed on the MRC database. It was determined that

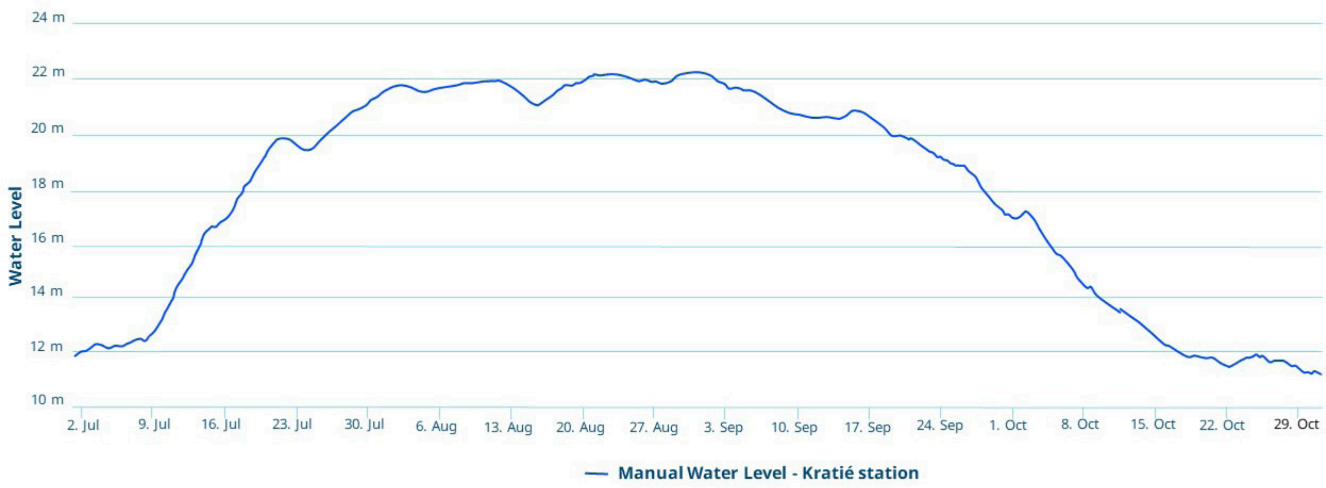


Figure 2:
Mekong River manual water table from Kratié station for the main flood July – October 2018 (own elaboration after MRC, n.d.)
Source: https://portal.mrcmekong.org/data–catalogue

July–October 2018 are best suited, due to a longer increase in discharge & water level of the Mekong River, which raises the likelihood for usable Sentinel–1 images (see Figure 2). Additionally, rainfall during this period occurred, which can provide insight about local sub–basin dynamics.

As a second step, a selection of Sentinel–1 images on the ESA distribution platform[40] was made to represent the documented rising and falling water tables around Kratié.
In continuation, all selected raw images were downloaded and pre–processed, following the methodological steps outlined by Kiran et al.,(2019), using the ESA SNAP software with an automated graph builder. Next, the individual histograms displaying backscatter intensity in dB were assessed and specific threshold points defined, using the distinctive low backscatter intensity of surface water.
Lastly, binary water mask images were created through the application of a simple threshold method. Results are then exported, clipped, polygonised, and analysed. The map, presented in Figure 3 displays the rising water levels in July and August 2018. For validation purposes, a suitable Sentinel–2 optical image (25 July 2018) is used to create a water surface indicator[41] and compared to the binary flood map of the respective timeframe, displaying a high compliance with the SAR mapped inundation.

A baseline for the analysed flood event with a comparative image from the dry season was determined to be 8 m Mekong water level and equivalent to 0 m water level change. The flood peak from the event discussed was observed on the 22nd of August 14.23 m above this baseline. Visual inspection of Figure 3 A) + F) illustrates that overall, no significant amount of urban centre was flooded during the event. However, Figure 3 B) signifies, that several roads were flooded, leaving some communities completely isolated during the flood. Furthermore, Figure 3 C) shows a subbasin of the Prek Te with increased flooded surfaces on 17 July. A correlation with a week of consistent rainfall and the flooding of significant areas southwest of the city as visible in Figure 3 D), indicates an influence of the local tributary to the flood dynamic in Kratié.
Lastly, Figure 3 E) shows the likely location of an embarkment breach during this period. When comparing the rising water levels shown in Figure 3 to receding water levels, the estimated embarkment breach can be spatially identified at 12°26’36” N 106° 02’ 43” E and a receding of the flooded area more closely related to the changes in the Mekong water level with the major breech occurring between ~10 m & ~11 m water level change. The analysed event from 2018 reached Mekong River level of maximum of 22.23 m during its peak, which means that the alarm level was barely overtaken, but on the other hand that the flood level was not triggered.
The interpretation of these images concludes that large amounts of the Mekong riverine landscape were consistently flooded between the 25 of July – 23rd September 2018, corresponding to a Mekong water level changes above ~10m. Several communities were already impacted by the floods of 2018, which leads to the question if the

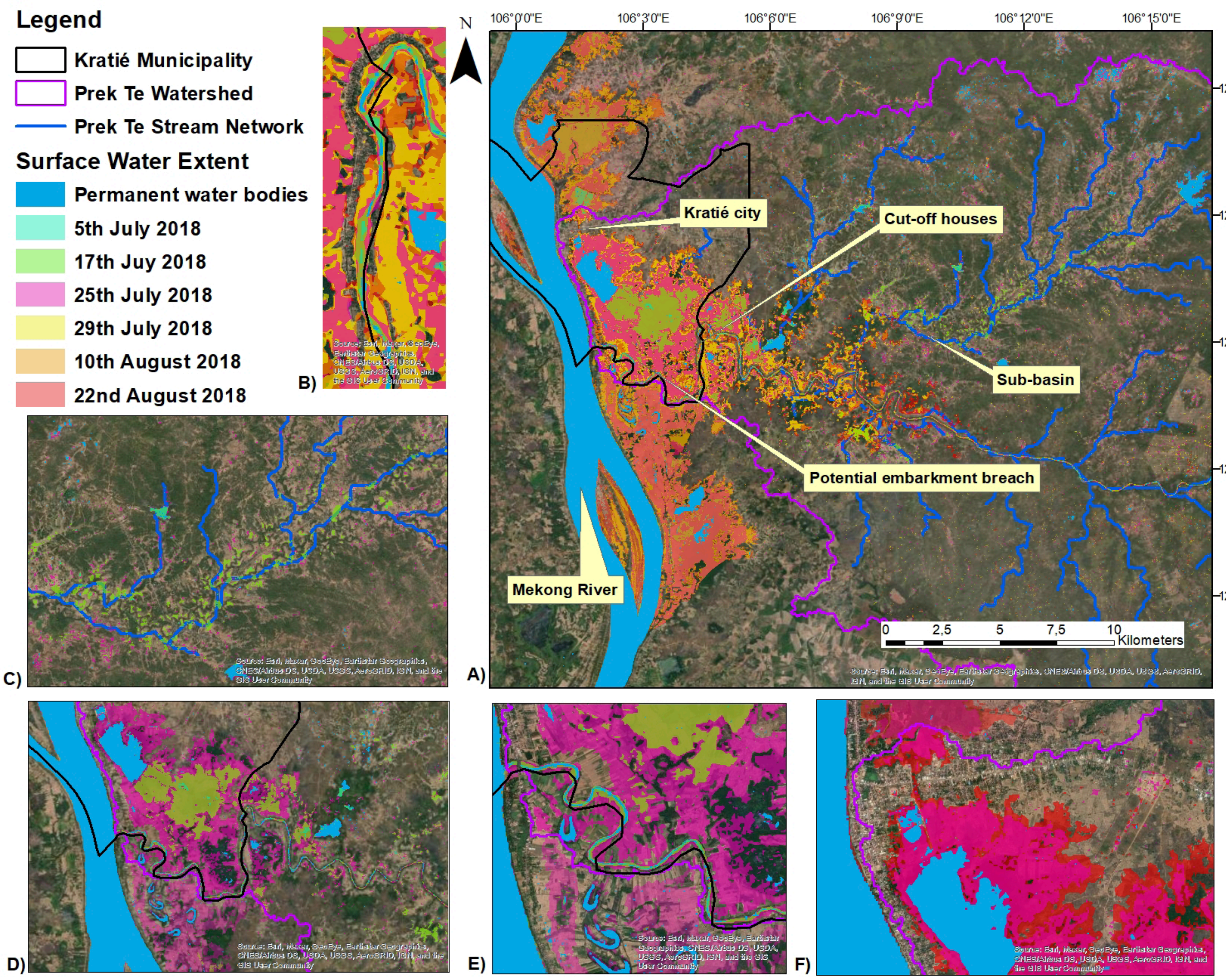
alarm level should be adjusted to provide sufficient lead time for them to prepare. Furthermore, large agricultural areas were flooded over the course of several weeks, even after receding water levels and cause potential significant loss of crops.

Flood management planning measures are recommended to focus on respective flood monitoring and early warning, an inquiry into the feasibility of structural measures, including embarkment improvements on the identified Prek Te breach to withstand future water level changes >15m. The local subbasin could be included in the local flood management strategy, to account for dynamics near the Mekong/ Prek Te confluence. The analysis further suggests a relation between the flooding and water level changes >10 m in the Mekong River, pointing out the potential occurrence of a backflow from the main river south of Kratié at a water table, which provides a base for further investigation or redirection of flood water (see MRC 2010b). Water retention measures could be applied to counter not only flood hazard, but further establish storage reservoirs for the dry season.[42]

Conclusion

This part of the study has introduced relevant flood inundation mapping methods and successfully applied the Sentinel–1 SAR binary threshold technique. Furthermore, the potential for flood management planning is outlined and suitable recommendations introduced. The significant relevance of the Mekong River in the existing flood dynamics was connected with specific water level changes and the potential role of smaller tributaries outlined. Flooded areas around Kratié were identified, corresponding to specific spatial and temporal dynamics, therefore allowing for an interpretation which flood warning and monitoring suggestions could be applicable as an improvement to the existing local management. Especially the identification of where and when the tributary river embarkments

Figure 3: Kratié flood inundation map with rising water level and flood peak in 2018 – A) Overview B) Cut–off houses C) Sub–basin with inundation extent D) Prek Te /Mekong confluence with inundation extent E) Potential embarkment breach inundation extent F) Kratié city with inundation extent Source: Sentinel–1 imagery accessed (ESA Copernicus Hub), Streamnetwork & watershed outline (NASA SRTM), Municipal Boundary (DIVA GIS)



are breached allows it to be possible estimate necessary structural improvements to the current flood management. The applied approach has a high potential for automatic integration into near real time web–based application and can help to inform the public, decision makers and other stakeholders before, during and after flood events. Furthermore, this methodology can be transferred and applied from a local to a regional or even national level to enhance the understanding of flood dynamics, review, and fine tune existing flood management practices with open–source data. However, the gained information can only act as guidelines. Before a final application, detailed investigation, and collection of ground data for realistic and feasible improvement should be conducted, based on the identified areas of interest. Overall, it can be concluded that the outlined approach can certainly help to fill existing knowledge gapsin regions where data is lacking.

Part II: Replicable open source–based risk methodology and potential resilient adaptation

Isabelle Knauf, Frederic Hebbeker, Uzabi Baidar & Ololade Shokan

<u>State of the art, methodology and application</u>

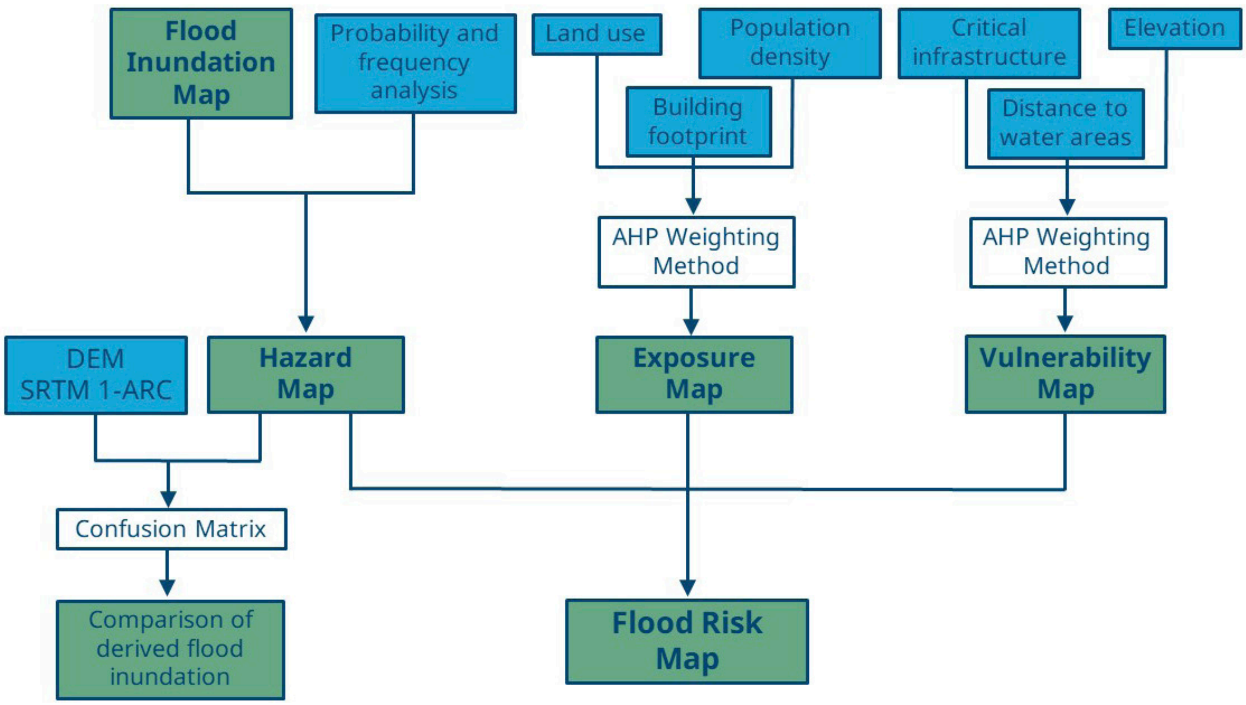
Flood risk mapping:

The information generated from the analysis of the flood risk is important and useful to make plans and interventions on preparedness, early warning, response recovery, and mitigation of flooding.[43] In this part of the study, spatial flood hazard, –exposure and –vulnerabilities are considered.[44] In order to determine the influence of the different input factors, a weighting method is applied (see Figure 4). In a last step, the three components are combined to generate the risk map.

Hazard:

The probability and frequency of inundation as well as the flood extent derived from the analysis of satellite images in part 1 of the study are calculated as the main input factors to generate the hazard map. In a first step, the probability and return period of inundation are calculated with the Gumbel method.[45] Data about the highest peak water level from each year for the past 20 years at the station in Kratié

Figure 4:
Risk mapping – Workflow diagram with inputs (blue), results (green) & methods (white)
Source: Author



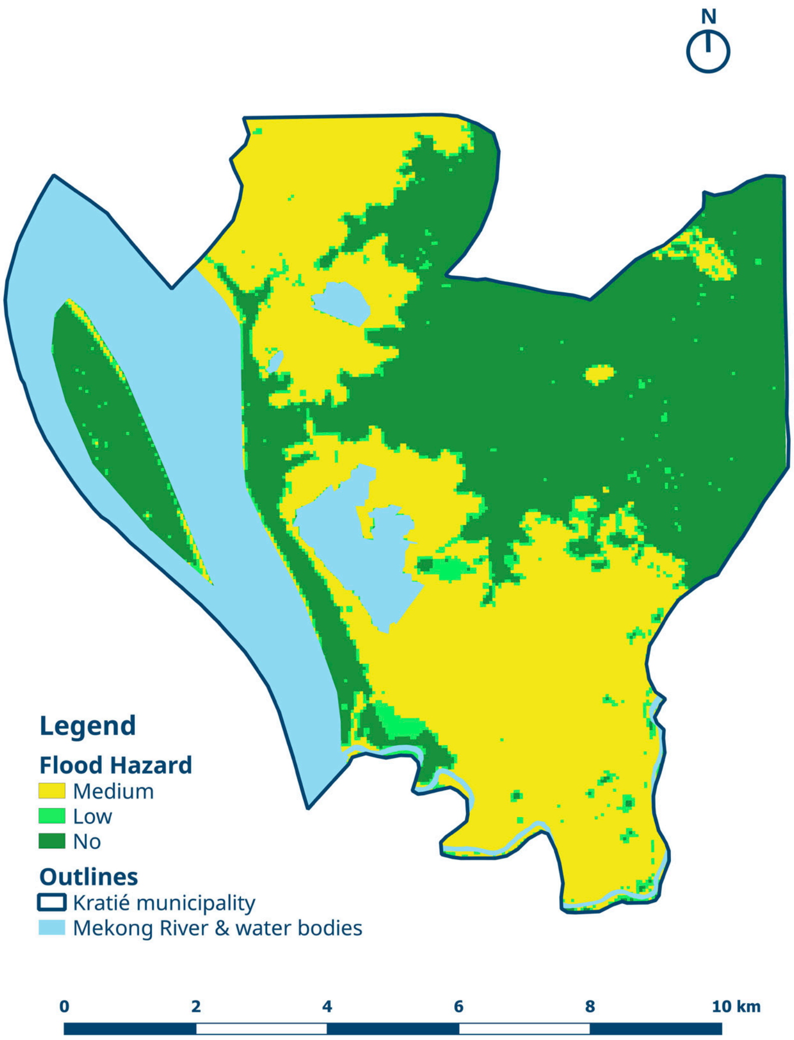
are derived from the MRC database (n.d). For the calculation, peak water level from every year is required. The acquired water levels are ranked by height to calculate the probability (Rank/(n+1)) and return period ((n+1)/Rank).
After visualising the results in a diagram, a linear equation can be determined to calculate the water level in dependence to the return periods:

$$y=1.4013 \ln(x)+20.06$$

Using this equation, return periods for the different water levels can be calculated as displayed in Table 1.

Flood Return period (Years)	Probability	Water Level (m)
1	100%	20.1
5	20%	22.3
10	10%	23.3
25	4%	24.6
50	2%	25.5
100	1%	26.5
200	0.5%	27.5

The highest water level within the previous 20 years was found to be 22.98 m (MRC n.d). Based on the identified return periods, four hazard categories are identified as a base to evaluate corresponding satellite images. Higher water level indicates higher hazard:



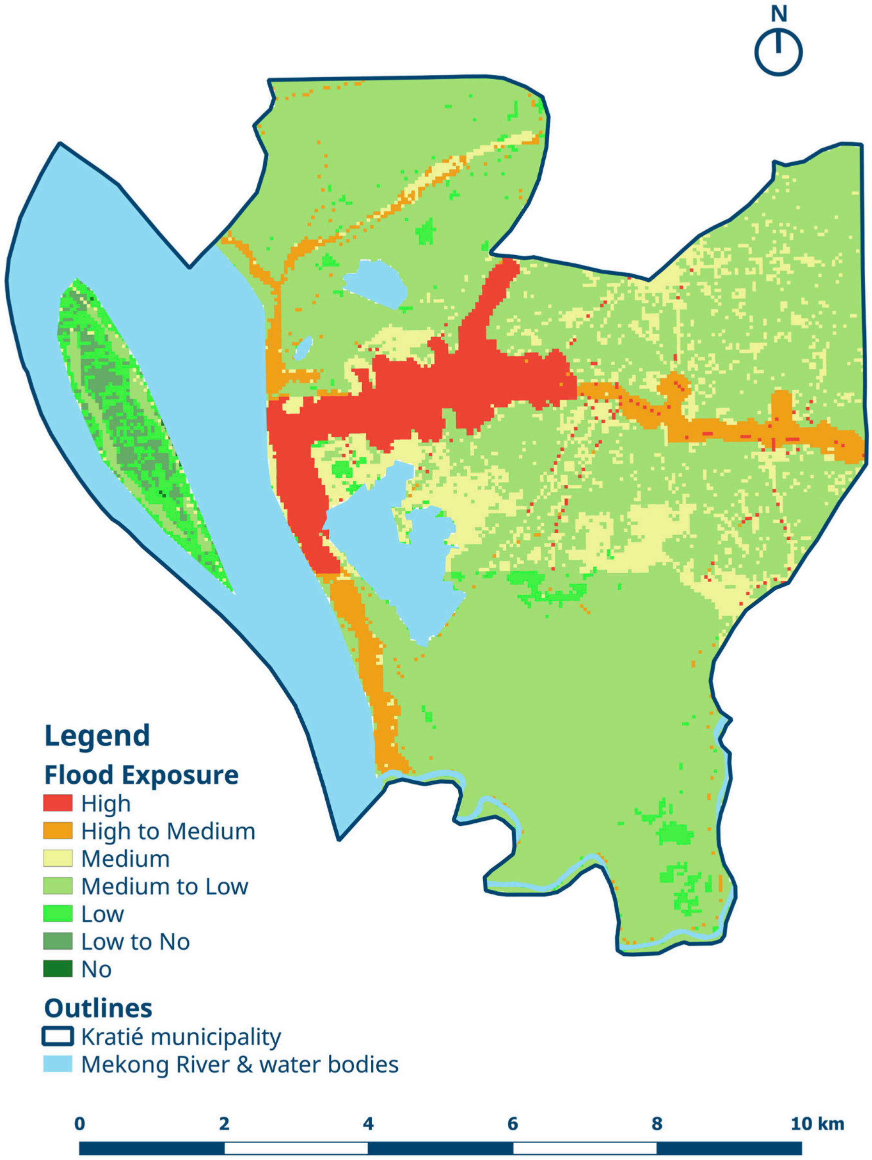
1. No Hazard	
2. Low Hazard	20.1 m water level, 1-year flood with a probability of 100%
3. Medium Hazard	21.6 m water level, 3-year flood with a probability of 33%
4. High Hazard	22.98 m water level, 8-year flood with a probability of 13%

Table 1:
Flood return period, probability, and corresponding water level, based on MRC data.

Figure 5:
Flood hazard map (Generated in QGis – Datasources: DIVA Gis (n.d.), UGSG (n.d.) and Copernicus Sentinel data 2018, ESA.)

Satellite–based images form part 1 of this study are then assigned with a respective return period and spatial hazard distribution where flooding occurred as displayed in Figure 5. A maximum water level in 2018 of 22.23 m corresponds to a Flood that has a statistical return period of 5 years and according to the data of the previous 20 years is representative for a Medium Hazard event. These results are in addition evaluated with a comparison of available elevation maps.

Figure 6:
Flood exposure map (Generated in QGIS. – Data sources: Built-up – GeoNode (n.d.), Land use – USGS b (n.d.), Population – SEDAC (n.d.)



Exposure:
The flood exposure map for this study is generated, using a weighted overlay analysis, with the application of information on land use/land cover, population density/distribution and building footprints to analyse flood exposure.[46] As the human population continues to grow, settlements keep expanding and human activities continue to grow in low–lying areas, often in combination with inadequate drainage infrastructure which increases the level of exposure.[47] For this study, population density/distribution data used was downloaded from the gridded population of the world (GPW). Land use/land cover as the selected second component of the exposure map was generated with a supervised classification of Landsat 8 images under the application of the maximum likelihood method, which groups cells with similar reflectance values. Six classes are generated from the classification: water bodies, riverbed, forest, grassland, developed area, crop land and bare land. Generalised images are reclassified to reduce error and to improve the accuracy of the classification. The final analysis was computed by weighted sum overlay of the individual layers applying Analytic Hierarchy Process: population (40%), land use (25%), and building (35%). Each indicator was assigned scores based on their relative importance and overall scores linked to a respective exposure category as shown in Figure 6.

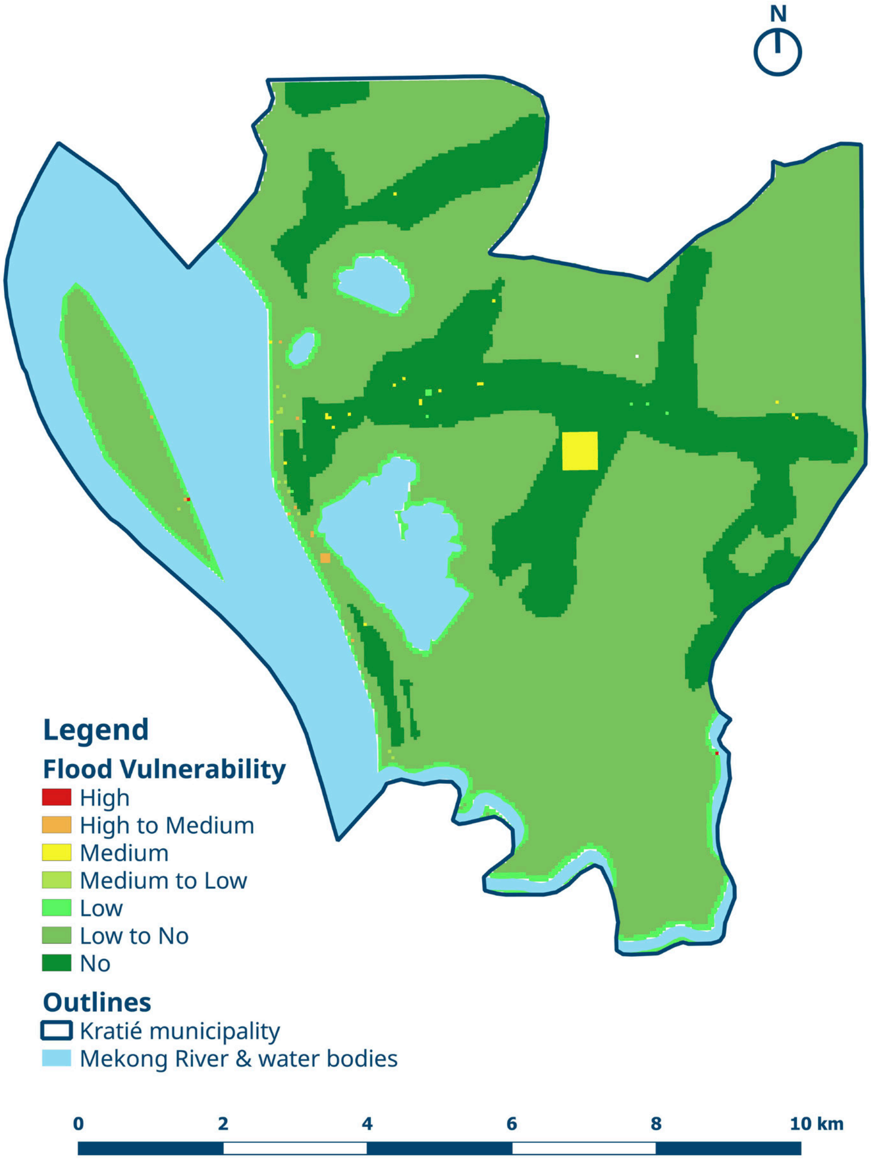
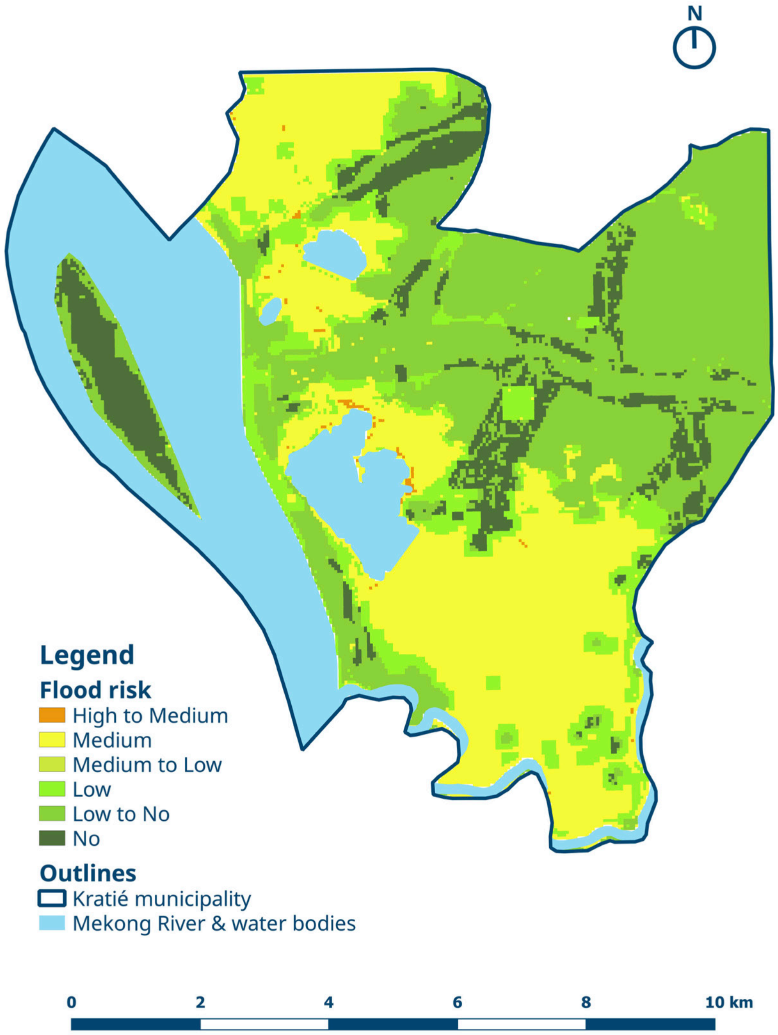


*Figure 7:
Flood vulnerability map
(Generated in QGIS. – Data sources: Open Development Cambodia (n.d.), Google Maps, OpenStreetMaps, DIVA GIS, n.d.)*

Vulnerability:
Several aspects include economic, social, physical, and environmental considerations. In order to determine economic vulnerability, residential buildings, special–use buildings (hospitals, schools), public infrastructure and agricultural land play a relevant role. For social vulnerability, population density, risk perception, income levels and spiritual values can be considered. Pollution, erosion and open spaces are potential input data for environmental vulnerability.[48] This study only applies aspects of economic vulnerability with a focus on most vulnerable infrastructure, such as hospitals, schools, water supply infrastructure, electricity substations, airports and police stations. These systems are essential to react during a flood event and, crucial if affected by a flood or where the most vulnerable people are located, e.g., kids and sick people. Ports, fuel storages, the central markets, religious points of interests and touristic spots were also included in critical infrastructure but ranked lower in their importance. The data to locate the CI was obtained from Open Development Cambodia[49] (n.d.), Google Maps and OpenStreetMap and visualised in in a combined GIS layer. A further input factor is the distance of buildings to the flood origins assessed in study part 1. Afterwards, each infrastructure object received a, according to its category of vulnerability which is displayed in Figure 7.

Figure 8:
Flood risk map based on the Flood hazard, – exposure, – vulnerability maps (Generated in QGIS. – Data sources: DIVA GIS (n.d.), UGSG (n.d.) Copernicus Sentinel data 2018, ESA. GeoNode (n.d.), SEDAC (n.d.), Open Development Cambodia (n.d.), Google Maps, OpenStreetMaps,)



Risk:
A combination of the previous hazard, vulnerability and exposure assessments is used to derive the final Flood Risk map, displayed in Figure 8.

The results indicate that the city of Kratié, includes as highly exposed (Figure 6) and vulnerable areas (Figure 7), which however are mostly situated in zones of low hazard (Figure 5) that transfer to an overall medium or low risk. A key factor in this result is the topography (Figure 1) that protects the urban area from flooding. Furthermore, the low population and infrastructure density outside the urban area, which is in focus of this analysis contributes to the results. The risk map reflects that few areas in Kratié are at high risk, except buildings found in medium hazard zones. Flood plains generally provide medium risk, mostly located South and North of the city, where cropland dominates. A further enhancement of the outlines analysis can be made if economic and social importance of these agricultural lands are documented and included into the vulnerability assessment.

Potential adaptation strategies to increase Flood resilience in Kratié:
Potential strategies aimed to improve flood resilience and increase protection in Kratié, can be made on the basis of the outlined risk assessment. Resilience strategies aim to increase and optimize prevention and preparedness to cope with flood impacts.[50] Three conceptual frameworks of resilience are explored, which are relevant for flood management Zevenbergen et al.,(2020).
Engineering resilience strategies describe planning, architecture, and building technology focussed on flood hazard that apply specific design or structural construction features in flood risk areas that reduce the consequences of the flood.[51] Integrating building codes, materials and mainte-

nance to protect communities is critical. Applicable measures in Kratié can include temporary floating walkways, upgrading of vulnerable houses or roads above ground level and building flood defenses, as applied in other flood–prone areas in Cambodia.[52]

Ecological resilience strategies on the other hand prioritize the application of Nature-based Solutions. It includes measures like constructed wetlands or natural drainage corridor creation to discharge wastewater and/or stormwater. Permeable pavements in urban centres on the other hand can infiltrate, treat, or store rainwater. Furthermore, the application of bioretention through underground structure and aboveground plantings (Stormwater tree pits) can add to the collection and treatment of stormwater. Stormwater runoff volumes are reduced, and groundwater recharge rates increased. Regular river trenching can support consistent natural surface runoff in urban centres, while open riverine landscapes offer an opportunity to open widened and deepen rivers or floodplains. Subsequent technologies like rainwater harvesting can be beneficial for flood management, as they collect and store rainwater.

"Social–ecological resilience" describes the ability of a social–ecological system to absorb change and disturbance without shifting to a new regime with a different set of processes and structures.[53] Practices involve local communities and include management of fluvial and pluvial floods through local measures, flood forecasting, and emergency planning.[54]

Aside from the mentioned strategies, communities should have access to governance strategies.[55] Appropriate policy and spatial planning, smart design of flood–prone areas, reconstruction, and rebuilding plans can further be important preventive measures to decrease the exposure of people and property.

Conclusion

The methodology outlined in part 2 of this study applies a desk–based Flood risk assessment that is relatively simple and uses open–access information. The distinction of three risk components provides a clear guideline, what type of information is needed at which part of the assessment and eases the data collection process in future applications. It provides reliable information of the spatial risk distribution in the municipality of Kratié, with the emphasize that at a current stage of development, concerns lie primarily in peripheral areas. However, this can provide important guidelines for the planning of future urban development. Decision makers can be pro–active identify which zones carry risks and are provided with alternative options. Furthermore, suitable strategies to increase the resilience of Kratié are listed with an important mixture of grey and green solutions respectively.

1 *Campbell, 2009*
2 *MRC, 2005*
3 *Kummu et al., 2010*
4 *HRF, 2018*
5 *Dekker et al., 2021*
6 *Räsänen et al., 2017*
7 *ADB, 2018 & Sithirith, 2021*
8 *Dekker et al., 2021*
9 *MRC, 2010a*
10 *Lehner & Grill, 2013*
11 *https://portal.mrcmekong.org/data–catalogue*
12 *MRC, 2020a, World Bank & UNISDR, 2013; CFE–DM, 2017; An, 2014*
13 *World Bank, 2016*
14 *MRC, 2010a*
15 *MRC, 2011*
16 *MRC, 2016*
17 *MRC, 2020a*
18 *MRC, 2020b*
19 *Dekker et al., 2021*
20 *MRC, 2020a*
21 *Wang et al., 2002, Huang et al., 2018*
22 *Wang et al., 2002*
23 *Islam et al., 2010; Kordelas et al., 2018*
24 *Huang et al., 2018*
25 *Elkrachy, 2015*
26 *Aggarwal et al., 2016*
27 *Tulbure et al., 2016*
28 *Qi et al., 2009*
29 *Mason et al., 2021*
30 *Morelli et al., 2019; Kyriou & Nikolakopoulos, 2015*
31 *https://www.un–spider.org/advisory–support/recommended–practices/recommended–practice–flood–mapping/step–by–step*
32 *UNOOSA, n.d. c*
33 *Perrou et al., 2018*
34 *Carreño Conde & De Mata Muñoz, 2019*
35 *Jain et al., 2018; Yang et al., 2021*
36 *Perrou, 2017*
37 *Perrou et al., 2018*
38 *Twele et al., 2016*
39 *Dekker et al., 2021*
40 *https://scihub.copernicus.eu/dhus/#/home*
41 *mNDWI after Xu, 2006*
42 *Sithirith, 2021*
43 *Smith et al., 2016*
44 *Rincón et al., 2018*
45 *Makkonen, 2006*
46 *Roy & Blaschke, 2015*
47 *Rincón et al., 2018*
48 *Rincón et al., 2018*
49 *Open Development Cambodia – Organizations OD Mekong Datahub*
50 *Gersonius et al., 2016*
51 *Garvin, 2012*
52 *Flower and Fortnam, 2015*
53 *Walker & Salt, 2006*
54 *EA UK, 2012*
55 *Driessen et al., 2018*

Trinh Duc Tran, Robert McClelland, Bony Pham, Guenther Straub, Thanh Nguyen, Anh Minh Vu

Urban Flooding in Ha Noi

Assessment of Low Impact Development Measures or Nature-based Solution for Mitigation

Introduction

Worldwide, there are now more people that live in cities than in rural areas. An estimation from World Bank shows that 55% of world population lives in cities which generate more than 80% of global GDP. Urbanisation both brings potential economic growth as well as challenges to meet the demand of its population for basic services, adequate technical infrastructure, and affordable living conditions. At the same time, as cities population grow, their exposure to climate change and disaster risk also increases. In recent years, there have been reports of increasing risks for urban areas such as heat island effect, floodings, air–water pollution and climate extreme events.

Newly developed urban cities and old cities alike currently face critical challenges on its design for resilience to meet the impacts of climate change especially in aspects of water management. Traditional approaches to design and operate urban water system has relied on past performance of natural systems and the extrapolation of the past conditions for the system's useful operational life. Within the last decade, plenty of examples show uncertainty due to climate change and have severely impacted the performances of urban technical water infrastructure. It is currently well accepted that the urban water management concept with strong reliance on engineered infrastructure and lack of connection with natural conditions upon which the cities are built in, is highly unsuited to address current and future sustainability issues.[1]

Case Study Area and Method

Ha Noi is the second largest city of Vietnam and the nation's capital, embedded in the Red river delta and maintaining strong connection with the Red river system and its downstream tributary that gradually becomes semi–natural channels inside the urban. After the merger of districts and neighbouring province, Ha Noi became a metropolitan area with total area of 3,358 km^2, including 29 subdivisions, a population of 8.246 million people and density of 2,455 people/km^2 respectively.[2] The population growth of Ha Noi was 1.3 million people from 2009 to 2019 corresponding to average population growth of 2.2%/year aggregated for the Ha Noi area with the expansion, or 3%/year for the old quarter[3], with half of that is the estimated migration population growth.[4] Ha Noi city has one of Vietnam's most rapid urbanisation rates with extensive building and infrastructures construction in the peri–urban area (Figure 1).

The climate of Ha Noi can be characterised as tropical, with 4 distinct seasons. The rain season normally starts from May and lasts until October with the highest rainfall in August (an average rainfall of 312 mm at Lang station). Every year Hanoi has 145–180 precipitation days (the total annual average rainfall of 1671 mm for period from 1971 to 2020), of which about 5–11 days have precipitation over 50 mm and 1–4 days with precipitation over 100 mm. The highly concentrated rainfall during the rainy season in combination with the low terrain of the Ha Noi (average altitude is 5–10 m above mean sea level), where many areas have elevation significantly below the Red River (an average elevation of +7 to +8 m) makes many locations in Hanoi vulnerable to flooding during the rainy season (Kefi et al., 2018).

According to one of the surveys carried out to categorize and document the locations of frequent flooding in Ha Noi show, that 20 experience recurring severe flooding which can last up to 18 hours. Results of the survey also show that with small rainfall the typical standing water level on the street

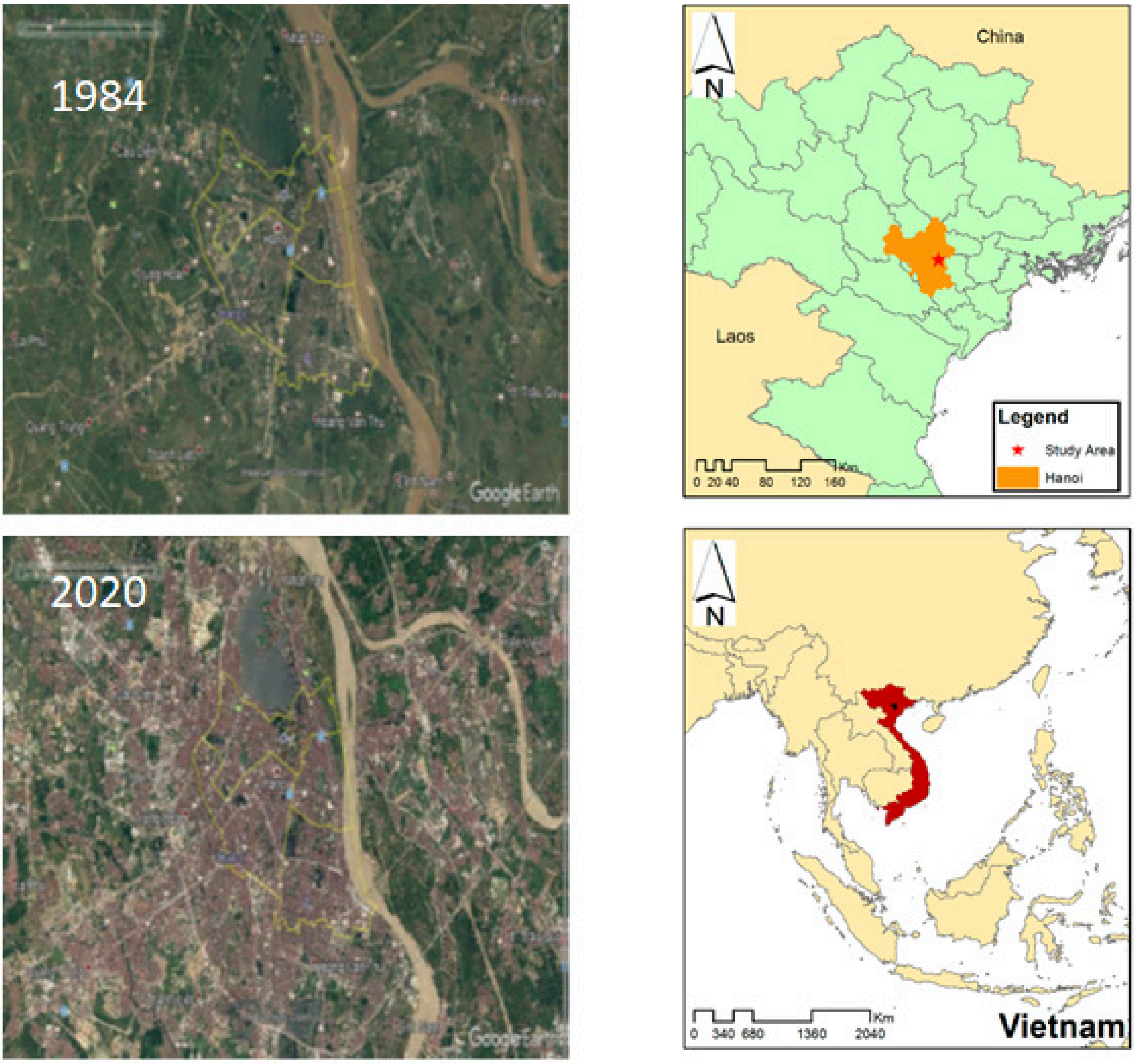


Figure 1:
Study area and the urbanisation progress through Google Earth (Image: Landsat/Copernicus) (Red river flows through the middle of the city which has been protected with dike system) (adapt from Kefi et al,) (Kefi et al., 2018). Exclude from Creative Commons License 4.0

ranges 10–20 cm while during the medium and heavy rainfall events, the flooding depth increased significantly from 30 cm to 70 cm and up to 100 cm particularly in some locations.[5] Ha Noi urban drainage company has maintained a website to track, document and issue warnings on the flooding locations during rainfall events to support citizens and local traffic navigation.[6]

From the natural, historical, and infrastructural point of view, the flooding of urban Ha Noi area is a compounded effect of increased urbanisation process, the inadequate infrastructure planning, severe precipitation events due to climate change and the lack of low impact development measures (LID) application. LIDs are suitable infrastructure measures for urban area as it would provide co–benefit on urban living condition, environmental as well as storm–water management. LID has been shown effective in urban area to respond to urban flooding as it provides more water retention and evaporation capacity to urban surface area to mediate the extreme urban hydrological cycle[7] at the same time it also provides cooling effect or water and air quality control to the local area.

This report summarizes the assessment of LID in storm water management and provides some suggestion for future adoption of the low impact development approach as well as consideration for scaling up for Ha Noi area.

The LID assessment was carried out for an area of 0.37 km^2 in Hoan Kiem district,

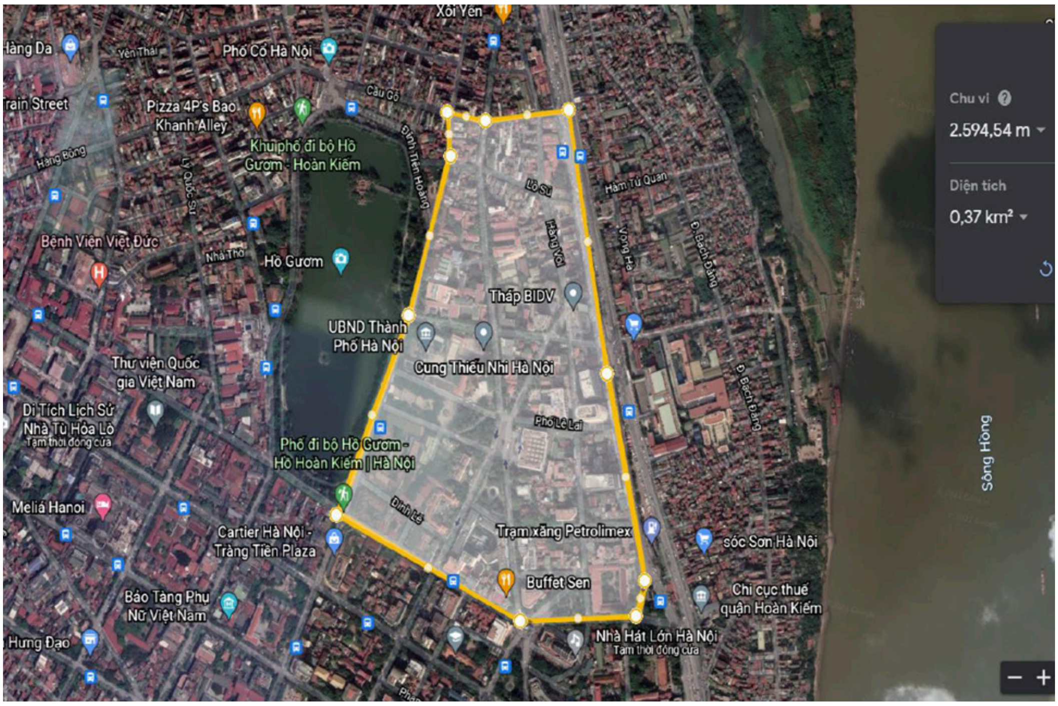


Figure 2: Delineation of the case study area in SWMM model: The boundary of the study area

Figure 3: Delineation of the case study area in SWMM model: Delineation of catchment area based on the topology, the location of manholes and sewer network in SWMM model (red circle is the simulation note for calibration between observed and simulated flood event)

one of the four original urban districts in Ha Noi, next to the Hoan Kiem lake and Red river dyke. Hoan Kiem district has the highest population density of all districts in Ha Noi with population density about 33,662 person/km^2, which is 137.3 times higher than the national population density. As a result, the area has very low sewer density of 0.013 m/person (on average the old central districts has sewer density of 0.3 m/person, much lower than other developed countries, from 1–2 m/person and above.[8] However, the per capita sewer density only partially reflects the drainage capacity of an area as the ability to drain depends on the total discharged volume versus the total collected volume on certain catchment area. Thus, an area with high density in the urban area always accompanies with low drainage density per capital that does not necessary translate into low drainage capacity.

Modeling method and SWMM model

Most of the case study area is covered with pavement, only a very small portion corresponds to green areas. Therefore, 98% of the surface area is impervious and the rest is pervious (green areas). To quantify the runoff and the potential LIDs' implementation, the entire study area was subdivided into 10 subcatchments based on Thiessen polygons[9] as implemented in SWMM programme. The applied criteria were on the basis of the influence area of each manhole in correlation with the slope values of the digital elevation model (DEM) proportioned by the local government. Figure 2 presents the model set up of the case study with the delineation, note and conduits as set up in SWMM model.[10] The pipe system is connected by 10 manholes (nodes), where the street runoff is collected. Finally, the system has 4 outlets discharging into the two main drainage directions.

The Horton method for infiltration and the dynamic wave routing for one–dimensional Saint Venant equations solutions were applied for flow routing. The Manning's equation to calculate the surface runoff and conduit discharge and flow were followed the description of Rossman et al.[11] Runoff, total inflow, and flooding were evaluated as metrics based on reduction rates of the peak flow on the whole system. The minimum reporting step time used to run the SWMM model was of 5 min (0.08 h). Rain events selected for calibration and validation are in the month of May 2021 with typical rainfall event is on May 11th 2021. Due to a lack of information at selected meteorological stations, the evapotranspiration parametre was estimated exclusively based on the model available parametres and referencing reports for Ha Noi area.

Modeling parametres

Initial parametre values by empirical values as recommended in the SWMM manual[12] were chosen, then calibrated and validated by the representative data of a rainfall event that causes flooding events in the area. Modified parametre values for comprehensive runoff coefficient and flooding event modelling are reported in the fifth column of Table 1. The simulation results satisfied the requirement of the total duration of observed and simulated flooding. According to observation data of Hanoi Sewerage and Drainage Company (SADCO) on May 11th, 2021, one flood spot with area 100x7 (m^2) was recorded nearby Thuy Tien hotel on Tong Dan street (Figure 2). The recorded flood depth was about 0.3 m and flood duration of 68 minutes lasting from 18:59 to 20:07. In SWMM simulation, urban flood results are reported in total volumetric flow amount and duration at simulated nodes which is the indicator for certain catchments and nodes with a surplus in flow, that exceeds the discharge capacity of the conduits, nodes or junctions.

Table 1: Calibration results of parametres in SWMM

No.	Parameter	Parameter Meaning	Range	Final Value
1	N-Imperv	Manning coefficients in impervious areas	0.006~0.05	0.015
2	N-Perv	Manning coefficients in pervious areas	0.08~0.5	0.12
3	Manning-N	Manning coefficient of the pipeline	0.011~0.24	0.013
4	S-Imperv	Depression storage in impervious areas/mm	0.2~5	3.0
5	S-Perv	Depression storage in pervious areas/mm	2~10	6.5
6	Max-Rate	Maximum infiltration rate (mm/h)	25~75	75
7	Min-Rate	Minimum infiltration rate (mm/h)	0~10	3.8
8	Decay	Infiltration decay constant (1/h)	2~7	2.5

Results and Discussion

Figure 3 shows the simulation result for the rainfall event causing flooding in the case study area on May 11, 2021, the maximum observed rainfall (5minutes) was around 15 mm leading to a very immediate surplus in the volumetric flow in the control node. The duration of rainfall event is about 1 hour with accumulated rainfall close to 80 mm/h.

After preparing natural conditions of study area and validating model, the modelling of Low impact development (LID) measures is necessary to build the scenarios which LID is applied. The simulation of LID scenarios in the form of bio–retention and permeable pavement were chosen to show the difference in surface runoff between sealed pavement and applied LID. The selected area for the application of LID was chosen to be all the public space available in the case study area (by adjusting the Max–rate and N–Perv for LID surface) to show the maximum LID mitigation potential in a typical rainfall event. Results shown in table 2 compare the infiltration rates and surface runoff of both modelled scenarios. The LID scenario gives significant higher infiltration rates (ca. 10 times) in comparison to the current situation scenario. As the result, the surface runoff in the LID scenario is significantly less (ca. half) than the surface runoff of current situation.

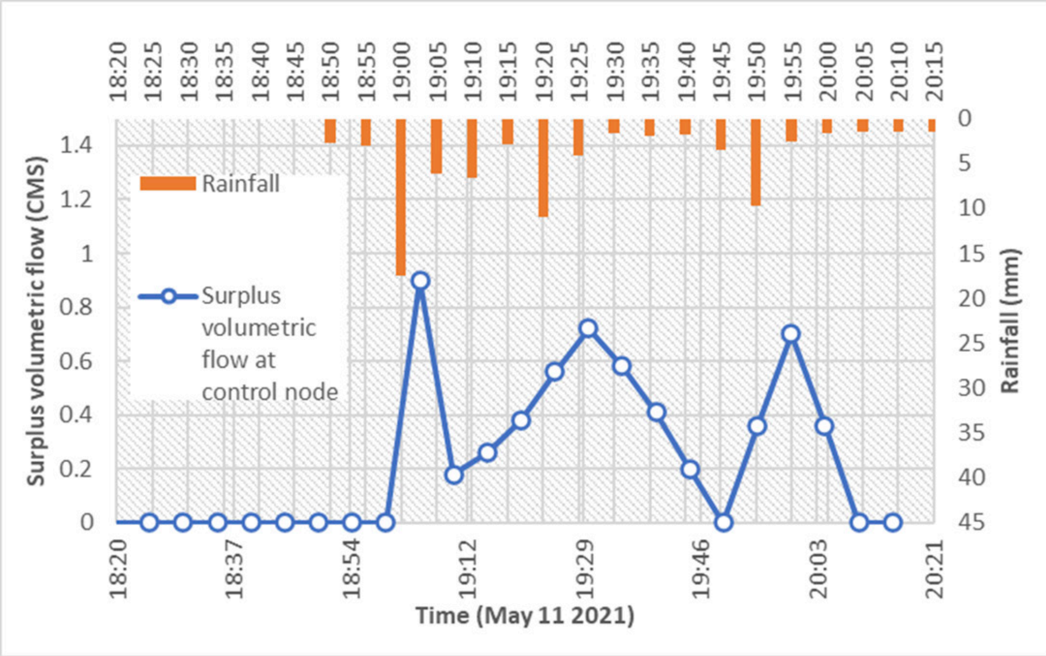


Figure 4: Validation for rainfall induced flooding event (May 11, 2021)

Table 2: LID (green infrastructure) flood mitigation effect of typical rainfall event

No.	Scenarios	Current situation	LID	Rainfall data
1	S0	X		10 years return period
2	S1		X	10 years return period
Parameter	**Unit**			
Infiltration rate	mm	1.27	18.77	
Surface Runoff	mm	22.48	9.75	
Flooding rate	$1x10^6L$	0.41	0.12	
External outflow (discharge)	$1x10^6L$	0.1	0.09	

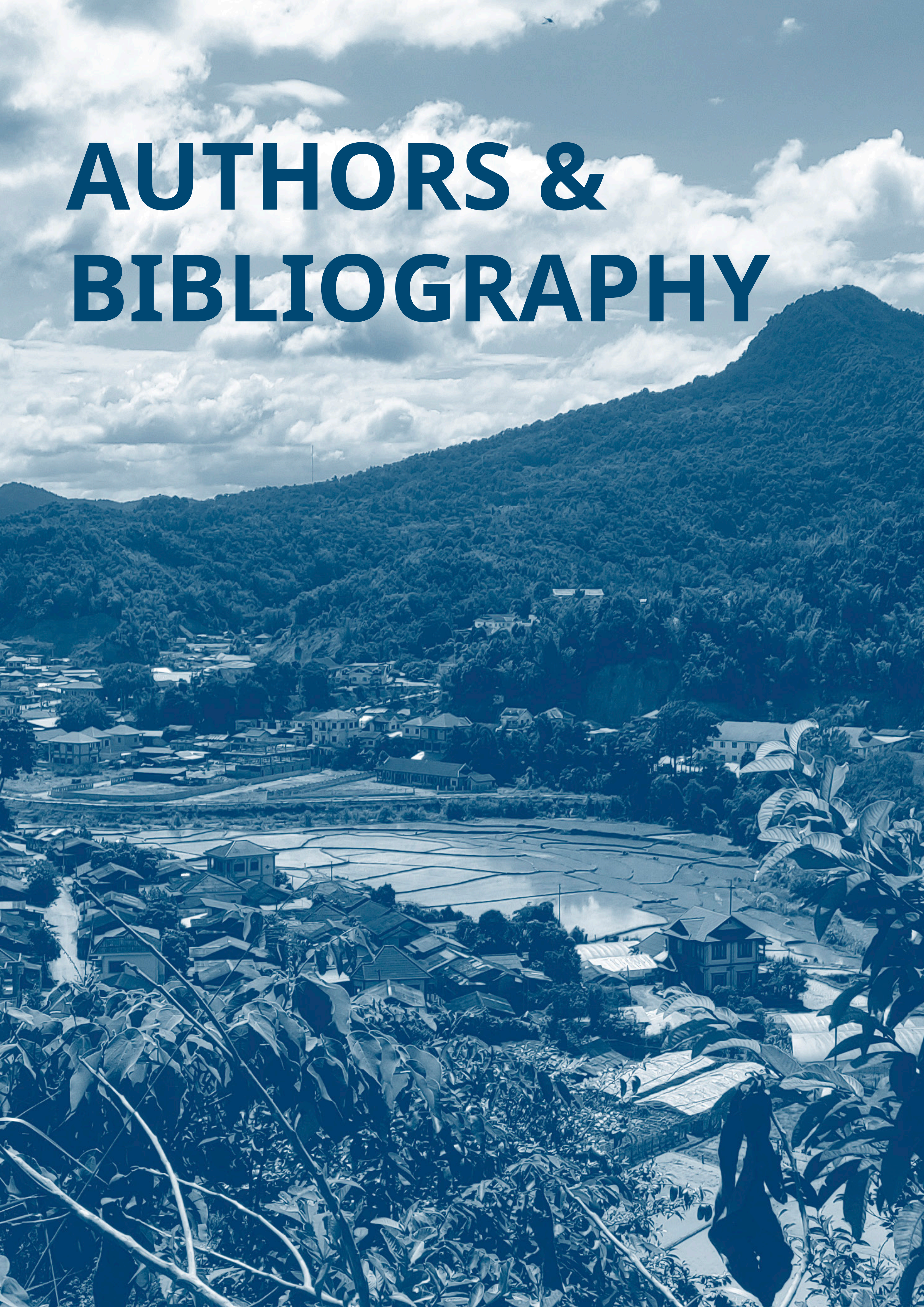
Conclusion

Urban flooding is a major challenge for Ha Noi city as there are more frequent severe flooding events in recent years. The city's urban drainage and environment company maintains a website to monitor and warn citizen on the location of urban flooding. Addressing the urban flooding challenge for urban area requires multiple efforts from infrastructure planning, management, and mitigation measures. This study assesses the performance of low impact development (a form of green infrastructure and nature-based solution) to mitigate the impact of urban flooding. Simulation result for the modelled scenario that applied LID to all available public space (pavement, park, walkways) has one magnitude higher in the total infiltration capacity thus reduce the surface runoff by 50% with the base case situation. With the combination of implemented different LID scenarios and expansion of drainage capacities, a cost–effective measure for the reduction of urban flooding in the densely populated area of Ha Noi would be provided, especially where land for technical infrastructure expansion is limited.

1 *Ashley et al., 2005*
2 *Leducq & Scarwell, 2018*
3 *Nong et al., 2018*
4 *Duc, 2016*
5 *Nguyen et al., 2020*
6 *Monitoring, 2022*
7 *Huang et al., 2020; Ruangpan et al., 2020*
8 *Lwin et al., 2015*
9 *Martin et al., 2020*
10 *Rossman, 2010; Ruangpan et al., 2020*
11 *Rossman, 2010*
12 *Rossman, 2010*

Source: PUW field trip, Sam Neua, Laos, 2022

AUTHORS & BIBLIOGRAPHY



Authors’ Bios

Uzabi Baidar
Researcher, specialising in Integrated Water Resources Management (M.Sc.) at Technische Hochschule Köln. She completed her bachelor‘s degree in Environmental Management (B.Sc.) from School of Environemtnal Science and Management, Pokhara University. Over the years, she gained expertise in environmental assessment and compliance studies, research, communication, and project management having served international NGOs, and in the private sector over the years. She received Deutscher Akademischer Austauschdienst (DAAD) and Carlo Schmid Fellowship. Her current interests include integration of Nature-based Solutions for water resources management, disaster risk reduction and climate protection.

Laura Dissel
Laura Dissel is a geographer with a specialisation in Integrated Water Resources Management at Faculty 12/ITT at Cologne University of Applied Sciences. During her studies she focused on the topic of water sensitive urban design and the integration of green infrastructure in urban areas, to increase the capacities and mitigation strategies of cities regarding climate change.

Matthew Dalrymple
Matt is a green infrastructure engineer and urban designer who lives in New York City. Currently, his work is focused on providing green infrastructure design services and developing nature-based stormwater management programmes for municipalities across the United States. Tools for Water Resilient Urban Design and Planning is informed by the work he completed during his time as an associated researcher and Fulbright Scholar at the Habitat Unit. Matt is motivated by creating functional urban spaces which provide both environmental and community benefits.

Torsten Grothmann
Dr. Torsten Grothmann is an environmental psychologist, has conducted research on adaptation to climate change for 20 years and currently works as a senior scientist at the Institute for Ecological Economy Research. Prior to his current position he worked in the interdisciplinary Ecological Economics Group at the University of Oldenburg, where he led the evaluation work package of the project „climate resilient future city Bremen (BREsilient)“. Before that he led several research projects on climate change impacts, vulnerabilities and adaptation options in various industrialized, emerging and developing countries at the Potsdam Institute for Climate Impact Research. Torsten Grothmann studied psychology, philosophy and business administration at the University of Bielefeld, the Free University of Berlin and the University of California, Irvine. He received his doctorate in psychology from the University of Magdeburg in 2006.

Christian Günner
Until the end of 2021 Christian Günner was Head of "Infrastructure Coordination and Urban Hydrology” at Hamburg Wasser. His main scopes were Strategic infrastructure coordination in the metropolitan region of Hamburg; investor relations; conception of future surface drainage taking into account, urban development, water protection, climate change, traffic development and infrastructure maintenance; support of large external projects of operational know–how transfer (so–called Water Operator Partnerships).

Bernd Gutterer
Dr. Bernd Gutterer started his professional career in business administration in the mechanical engineering industry. He studied sociology, economics, philosophy and environmental sciences at the University of Bremen and at the Paris Nanterre University. He received his doctorate at the Mercator University Duisburg on the subject "Sustainable Energy Supply in Rural Areas and

Sustainable Technology Transfer". After being active for thirty years in international scientific and technical cooperation (University Witten–Herdecke, BORDA, InWEnt, GTZ/GIZ) in Europe, Africa, Latin America, Middle East, South Asia and South–East Asia, he is responsible for the overall management of the PolyUrbanWaters project. Furthermore, he contributes his expertise in the design of complex multi–stakeholder and capacity development processes and in transformation processes for sustainable water management in urban areas.

Anke Hagemann
Prof. Dr. Anke Hagemann is since September 2021, co–heading Habitat Unit as a guest professor together with Elke Beyer during Prof. Philipp Misselwitz's sabbatical. She graduated in Architecture in Berlin and was a co–founder and editorial board member of the journal An Architektur. She was a research associate and assistant curator of the exhibition project Shrinking Cities, Berlin, and taught at the Institute for Theory and History of Architecture (gta), ETH Zurich, the Technical University of Stuttgart and the Master's Course in Urban Design at the HafenCity University Hamburg. In 2020–21 she was an interim professor for Urban Planning at BTU Cottbus–senftenberg. She has researched and published on global commodity production and urban spaces, holiday architectures in Bulgaria, urban mega–events, stadium architecture and the regulation of access. Her work is mainly concerned with exploring and visualising multiscalar spatial constellations and the social conditions of their production. She is a Principal Investigator in PolyUrbanWaters project as part of TU Berlin Habitat Unit research team.

Frederic Hebbeker
Researcher with a Geography background. Currently completing his M.Sc. in Integrated Water Resource Management at the TH Cologne. Research interests are primarily environmental assessments methods in conjunction with planning measures for disaster risk reduction. It specifically includes climate & water monitoring trough Reanalysis data, station data and field measurements. Further interests are water related risk assessments as well as Satellite and drone based remote sensing applications for various mapping activities. He has been part of the PolyUrbanWaters Team since 2020, with a current position involving management, coordination, and organization of activities.

Lucia Herbeck
Dr. Lucia Herbeck studied biology at the University of Mainz, the University of Glasgow and the University of Bremen, where she also received her doctorate in 2012. For many years she worked as a researcher in the field of aquatic ecology and gained project management experience in several international projects. Through a further engineering education in "Water and Environment" at Hannover University, she got in touch with the field of heavy rainfall and flooding as a result of climate change. Since 2019, she is head of the joint project "climate resilient future city Bremen (BREsilient)" at the Ministry for Climate Protection, Environment, Mobility, Urban and Housing Development of the Free Hanseatic City of Bremen.

Adrian Hodgson
Adrian has been an urban and environmental planning practitioner since 1999, with a professional and academic history focused on improving the liveability of less advantaged urban areas in lower–income countries. He currently works at the Habitat Unit of TU Berlin on "application, solution and user–oriented research" for the PolyUrbanWaters Project, Southeast Asia. His background includes numerous years of advisory on WASH/ FSM and urban planning assignments in Africa, SE Asia, and Latin America regions; several years in Malawi at the Zomba City Council as an Urban Planning and Development Advisor for GIZ, with a focus on "grass–roots" and participatory planning processes; research with

UN–HABITAT in Kenya into slum upgrading approaches applied around the globe; as well as four major citywide infrastructure rollouts in capital Australian cities.

Xhesika Hoxha
Xhesika Hoxha is an environmental engineer with a specialisation in Integrated Water Resources Management at Faculty 12/ ITT at Cologne University of Applied Sciences. Her main areas of research are assessing the potential of nature-based and hybrid infrastructure solutions, in order to improve urban water resources security for fast–growing secondary and tertiary cities in Southeast Asia (Laos, Indonesia, and Cambodia).

Isabelle Knauf
Isabelle did her Bachelor's degree in Energy and Water Management. During her studies, she was particularly interested in the sustainable management of water resources and international projects, which is why she pursued her Master's degree in Integrated Water Resources Management. Since completing her Master's degree in January 2022, Isabelle has been working as a project manager in the field of water, IT and environment.

Stefanie Knauß
Stefanie Knauß is a social scientist with a specialisation in Natural Resources Management and Development at Faculty 12/ ITT at Cologne University of Applied Sciences. Her main areas of research are assessing the potential of nature-based solutions and hybrid infrastructure solutions in the context of growing coastal tourism, in order to improve the conservation of ecosystems for ecosystem–based disaster risk reduction (Eco–DRR) and ecosystem–based adaptation (EbA) under climate change in Spain.

Quirin Luppa
Quirin holds a master's degree in evolutionary biology as well as in natural resource management and development with a focus on nature– and technology–based carbon dioxide removal technologies. After graduating from the University of Applied Sciences in Cologne, Quirin actively advises companies on individual climate strategies.

Robert (Bob) McClelland
Prof. Robert McClelland is the Dean of the School of Business & Management at RMIT University Vietnam. He is responsible for ensuring the quality and currency of the school's portfolio of undergraduate, postgraduate and PhD programmes. Professor McClelland holds a Master of Analytical Chemistry, a Postgraduate Diploma in Management and a PhD. in Virtual and Blended Learning for Business, all from Liverpool JMU in the UK. He is a Fellow of the Higher Education Academy, invited upon its inception in 2000. His expertise lies in the areas of Research Methods and Statistics, and he has supervised almost forty PhDs to completion.
He has worked on international projects funded by the National Health Service, and Office of the Deputy Prime Minister and Metropolitan Police in the UK, the European Union on Horizon 2020 and Erasmus projects internationally.

Rosa Miglio
Rosa is an Agricultural Engineer, with a Master's degree in Agricultural Engineering and a PhD candidate in Engineering and Environmental Sciences from the Postgraduate School of the Universidad Nacional Agraria La Molina (UNALM). She has been a Senior Professor at UNALM since 1980; she has been Dean of the Faculty of Agricultural Engineering. She teaches courses at the undergraduate, specialisation and postgraduate levels, in various master's degrees. She is a consultant in sustainable sanitation and wastewater treatment. She is a Renacyt researcher with ORCID 0000–0002–2214–2187, conducting projects in constructed wetlands, sewage sludge, emerging pollutants, swine effluent treatment. She has conducted more than 50 thesis works for undergraduate and grad-

uate students at UNALM.

Elise–Phuong Ha Nguyen
Elise-Phuong Ha Nguyen is an architecture and urban planning graduate from TU Berlin. She is part of the PolyUrbanWaters research team since 2021. Besides her teaching assistances at TU Berlin and the Vietnamese German University in Hồ Chí Minh City, Vietnam, her work is additionally infused with an intersectional approach in urban planning and architecture as seen in her work with ifa_diaspora.

Thanh Nguyen Long
Thanh is a Master student at the Integrated Water Resources Management programme jointly delivered by TH Köln, Thuyloi University and Vietnam Academy for Water Resources. Thanh has a background in Civil and Engineering with a focus on hydraulic engineering. Currently, Thanh is the staff of Central Irrigation Project Office of Ministry of Agriculture and Rural Development. His research interests include hydraulic modeling, hydraulic system design, application of GIS and remote sensing in water resources management.

Eka Permanasari
Eka Permanasari is an urban designer and she is particularly interested in research on how communities interact with nearby located water resources. She has researched community engagement approaches on Water-Sensitive issues for a more sustainable environment in tourism villages in Sleman, Indonesia and densely populated areas in Jakarta. She has worked with communities on flood mitigation through urban farming and subsoil biopores.

Rossana Poblet
Rossana is architect and urban planner, UN–Habitat specialist and PhD candidate at the University of Stuttgart in Germany. She was part of the Lima Ecological Infrastructure Strategy at ILPÖ and led the WWTP implementation. Since then, she keeps monitoring the LEIS results. Rossana has several years of professional experience in international cooperation and sustainable urban development and focusses on co–developing new approaches linking theory and practice, based on integrative concepts and participative processes. Her interest focusses on understanding connections between governance, people's processes, and ecological (infra)structures, and how effectively they could revert socio–economic, physical, and environmental injustices in cities and regions, including neglected and contested territories of the so–called Global South. She has extensive experience in integrative territorial planning and design and lives between Berlin and Lima.

Lars Ribbe
Prof. Dr. Lars Ribbe is the Dean of Faculty of Spatial Development and Infrastructure Systems at the Cologne University of Applied Sciences and a Professor for Integrated Land and Water Resources Management at the ITT. He has a Master's of Engineering and a PhD in the field of hydroinformatics. His key research areas are:
integrated river basin monitoring, modelling and management; strategies to cope with water scarcity, water access and pollution; and the water–energy–food nexus. He occupies a managerial role in the PolyUrbanWater project as well as providing expert advice on the processes and analyses undertaken by the project team.

Alexandra Rospigliosi
Alexandra is agricultural engineer graduated from La Molina Agrarian National university – UNALM, Lima, Peru. She has follow up the development of the implemented WWTP Children's Park, including the monitoring of water quality and people's perception. Alexandra is currently working in the direction of hydraulic and environmental projects related to irrigation systems, rural sanitation and management and recovery of ecosystems.

Sonja Schlipf
Since January 2020 Dr. Sonja Schlipf is re-

sponsible for the Coordination of RainwaterInfraStructureAdaptation at Hamburg Wasser. Her focus is on enhancing the co-operation processes to improve integrated rainwater management within the city of Hamburg.

Ololade Shokan
Ololade Shokan hails from Nigeria where she acquired her bachelor's degree in Geography and Environmental Management from Tai Solarin University of Education, Ijebu–Ode, Nigeria in 2015. She is currently pursuing her master's degree in Integrated Water Resources Management at Technische Hochshule (TH) Köln, Germany. Her current research interests include hydrological processes, flood prediction and integration with machine learning, and remote sensing.

Antje Stokman
Antje Stokman is landscape architect and professor of landscape architecture at HafenCity University Hamburg. In her research, teaching and practice, she deals with interdisciplinary issues relating to the transformation of urban landscapes with the aim of integrating ecological, infrastructural, social and aesthetic requirements. In 2009 she was awarded the Science Prize of Lower Saxony and international Topos Landscape Award in 2010. Her theories and projects have been presented in international exhibitions and published widely. She is a member of the Network Studio Urban Landscapes, the Chamber of Architects and the Association of German Landscape Architects.

Günther Straub
Günther Straub is an architect and urban planner with an additional Master degree in natural resources management. He worked as a design architect and is since 2001 affiliated at TH Köln. There he works there as lecturer, higher education developer and international project coordinator. His research interests are urban resources efficiency, efficient and resilient societies as well as higher education didactics and open online education. His regional focus is on SEA. Currently he is coordinating a cooperative master programme in Vietnam, projects addressing hybrid teaching and learning and is the TH Köln network coordinator for the open education platform ORCA.nrw.

Hasanatun Nisa Thamrin
Hasanatun Nisa Thamrin, better known as Icha, is an urban planner and has worked at Kota Kita since 2014. At Kota Kita, Icha has led participatory initiatives such as Women on Wheels to promote cycling amongst marginalised women in Solo and also a project to support urban poor civil society organisations to monitor public budgets. Icha has also played a key role in implementing the Urban Citizenship Academy programme at Kota Kita, which trains youth groups to develop urban initiatives. Prior to Kota Kita, she worked as a researcher at Universitas Diponegoro (UNDIP) in P5 lab, an urban planning research group that focusses on community–basedeconomies and participatory planning. As a Programme Manager, Icha is experienced in leading and organising community facilitation workshops and other stakeholder engagement activities that bridge communities and government.

Bony Pham Thuy
Bony is a Professional staff and project coordinator at the RMIT University School of Business and Development. Bony is also member of Sustainable Development Research Cluster at RMIT University Vietnam where she coordinates and joins research projects. Currently she is a member of the Urban GreenUp research project funded by Horizon 2020 programme looking at innovative Nature-based–Solution methodology and demonstrations in cities. Bony has background in public policy and business administration.

Trinh Duc Tran
Dr. Trinh Duc Tran is a researcher working in the area of environmental and water

resources management to support a sustainable use of natural resources and ecosystem addressing the societal and climate change challenges at the urban and river basin. Trinh is associated with Sustainable Development Research Cluster at RMIT University Vietnam where he leads research on innovative Nature-based Solutions addressing climate change, water management and urban development challenges for cities, localisation of water and environment related SDG targets in the national, urban and rural context

Christof Voßeler
Dr. Christof Voßeler a policy advisor for climate change adaptation at The Ministry for Climate Protection, Environment, Mobility, Urban and Housing Development of the Free Hanseatic City of Bremen. He is an environmental engineer and economist and worked several years in the fi eld of development cooperation. Since 2007, he is responsible for the development and implementation of climate change adaptation strategies in the Free Hanseatic City of Bremen. He is working in several practice–oriented research projects on climate resilience at provincial and municipality level and is a member of several national and international working groups on climate resilience.

Anh Minh Vu
Minh is a Master student at the Integrated Water Resources Management programme jointly delivered by TH Köln – University of applied Sciences, Thuyloi University and Vietnam Academy for Water Resources. Minh has a background in Water Resource Engineering. His research interest include application of GIS and remote sensing in water resources management, and hydrological–hydraulic modeling of basin water management practice.

Laila Wendel
Laila Wendel is a biologist studying Integrated Water Resources Management at the ITT at Cologne University of Applied Sciences. Her main area of interest is nature-based solutions in river restoration projects aiming to accelerate ecosystem recovery of modified riverine landscapes. For her master's thesis, she is currently researching the potential of virtual field trips for education and public outreach in the field of landscape planning and watercourse development.

Johanna Westermann
Johanna works as an urban designer and researcher for Bauhaus Earth, focusing on regenerative processes in the built environment. During her studies, Johanna engaged intensively with the topic of resilient urban design with a special focus on water, both in her design projects and in her work as a student assistant for the research project PolyUrbanWaters. Her work is infused with a particular interest in co–productive and participatory approaches.

Ania Wilk–Pham
Ania Wilk–Pham is an architect and urban planner and a member of Habitat Unit Research Team at the Technical University of Berlin. She is working at the interface of integrated planning and architecture. Her research interests combine the areas of extended urbanisation, community–based planning and co–production, participatory methods and community engagement in planning. Ania is part of the Polyurbwater research project (BMBF, 2019–2024), where together with the Habitat Unit team she focusses on development of integrated and participatory urban development approaches.

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Figure 1:
Assessment levels for effective transition (after Chesterfield et al., 2021)

Figure 2:
Project partners and pilot cities

Figure 3:
Work packages of PolyUrbanWaters Consortium, Source: PolyUrbanWaters

Figure 4:
Stages of Vision Building Process, Source: PolyUrbanWaters

2 Water Knowledge

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Figure 1:
The elements of Water Literacy. (adapted from Maniam et al., 2021).

Figure 2:
Main Components of Water Knowledge and its characteristics

Figure 3:
Sex–disaggregated data of participants in the survey. Source: own compilation, 2022

Figure 4:
Survey respondents according to their age/number or respondents. Source: own compilation, 2022

Figure 5:
Survey respondents' education level/number of respondents. Source: own compilation, 2022

Figure 6:
Do you know what a water source is? Source: own compilation, 2022.

Figure 7:
Selected photos representing water sources indicated by the survey respondents. Source: own compilation, 2022.

Figure 8:
Water use in Sariharjo Village. Source: own compilation, 2022.

Table 1:
Activities performed in connection to water resources. Source: own compilation, 2022.

Table 2:
Knowledge statement. Source: own compilation, 2022.

3 Tools for Water Resilient Urban Design and Planning

Mucke, et al., 2019

Höferl & Sandholz, 2017, p. 24

Figure 1:
Expected transformation corridors in Sariharjo
Source: Johanna Westermann, Matthew Dalrymple

Figure 2:
Riverbank Redevelopment and Land–Use Management Scenario 1
Source: Johanna Westermann, Matthew Dalrymple

Figure 3:
New development and
Commercial Uses Scenario 2
Source: Johanna Westermann, Matthew Dalrymple

4 Water ceremony

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Figure 1:
River network in Yogyakarta
Source: Pemkab Sleman modified by Author 2020

Figure 2:
The growing numbers of village tourism
Source: Author 2020

Figure 3:
Kepuharjo tourism village
Source: Author 2020

Figure 4:
Petung tourism village
Source: Author 2020

Figure 5:
Pandowoharjo tourism village
Source: Author 2020

Figure 6:
Brayut tourism village
Source: Author 2020

5

Rapid Assessment of Nature-based Solutions for Water Management

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Table 1:
Elements identified in the literature and included in the proposed framework.

Table 2:
Criteria and indicators. Summarizing overview of criteria and respective indicators for the assessment of NBS performance

Figure 1:
Rapid assessment framework for the overall performance of nature-based solutions.
Through literature review (table 1), relevant elements for the proposed evaluation framework were identified. After identification of regional challenges and local main goals, six criteria of overall NBS performance are assessed: 1) The performance in the main function (the desired main functions derive directly from identified regional main goals. Indicators for this criterion are location–specific and must be identified through literature research); 2) The provision of co–benefits (environmental, social, and economic) by the NBS; 3) Trade–off potential; 4) Financial feasibility; 5) Time efficiency and 6) Flexibility.

6 Challenges and future perspectives of a water–wise urban and neighbourhood development

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Figure 1:
The path to blue–gren (rain)water management
Source: Hamburg Wasser

Figure 2:
Source: Hamburg Wasser

Figure 3:
Source: Hamburg Wasser

7

Water-Sensitive Urban Design and Green Infrastructures in the Peruvian context

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Table 1:
Average results of water quality parametres.
Source: Sostenibilidad de un Humedal Artificial de Flujo Vertical, para el Tratamiento de aguas Contaminadas con fines de reúso, Garcia L. 2021

Figure 1:
LEIS multiscale and multidisciplinary integrative approach, Source: LiWa Project, http://www.lima–water.de/en/pp7.html accessed last 22.05.2022

Figure 2:
Participatory process to build the LEIS Principles, Source: LEIS Book, Eisenberg et al, 2013

Figure 3:
Combination of relevant characteristics in hydro urban unit, Source: LEIS Book, Eisenberg et al, 2013

Figure 4:
View of area before the project showing irrigation channel and vacant land, Source: Rossana Poblet, LEIS–LiWa Team, 2014

Figure 5:
Panoramic view of the project showing treatment system – constructed wetland and reservoir, productive green recreational area, and dry park and playground, Source: Evelyn Merino Reyna, 2014

Figure 6:
Principle of the structure of water treatment in the wetland (Descriptive Memory – Treatment of Canal Water in the Artificial Wetland WTL–Rotaria for the use in irrigation of the park in La Florida II – Chuquitanta.2014, Source: Rotaria del Perú, 2013

Figure 7:
LEIS team explaining the park design and the constructed wetland parts and functioning to the San Martin de Porres Major (2011–2014) Mr. Freddy Ternero and La Florida II residents during the WWT Children's Park inauguration, 15 August 2014.de reúso, Garcia L. 2021, Source: LEIS–LiWa Team, 2014

Figure 8:
Children under 10 years old enjoying recreation of healthy green areas irrigated with clean wastewater treated by constructed wetland, Source: Eva Nemcova, LEIS–LiWa Team, 2014

8 Living Labs for heavy rain and flood prevention

Figure 1:
Overview on processes in the living lab „Heavy Rainfall Prevention Blumenthaler Aue“
Source: Author

Figure 2:
Pauliner Marsch
Source: Meyerdirks

Figure 3:
Overview on processes in the living lab „Flood Risk Prevention Pauliner Marsch & Im Suhrfelde“
Source: Author

Figure 4:
Pauliner Marsch
Source: ecolo

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Table 1:
Flood return period, probability, and corresponding water level, based on MRC data.

Figure 1:
Map of the study area Kratié, Cambodia
Source: DIVA GIS, SRTM (USGS Earth Explorer) and Google Earth

Figure 2:
Mekong River manual water table from Kratié station for the main flood July – October 2018 (own elaboration after MRC, n.d.)
Source: https://portal.mrcmekong.org/data–catalogue accessed last 12.07.2023

Figure 3:
Kratié flood inundation map with rising water level and flood peak in 2018 – A) Overview B) Cut–off houses C) Sub–basin with inundation extent D) Prek Te /Mekong confluence with inundation extent E) Potential embarkment breach inundation extent F) Kratié city with inundation extent
Source: Sentinel–1 imagery accessed (ESA Copernicus Hub), Streamnetwork & watershed outline (NASA SRTM), Municipal Boundary (DIVA GIS)

Figure 4:
Risk mapping – Workflow diagram with inputs (blue), results (green) & methods (white)
Source: Author

Figure 5:
Flood hazard map (Generated in QGis – Data sources: DIVA Gis (n.d.), UGSG (n.d.) and Copernicus Sentinel data 2018, ESA.)

Figure 6:
Flood exposure map (Generated in QGIS. – Data sources: Built–up – GeoNode (n.d.), Land use – USGS b (n.d.), Population – SEDAC (n.d.)

Figure 7:
Flood vulnerability map (Generated in QGIS. – Data sources: Open Development Cambodia (n.d.), Google Maps, OpenStreetMaps, DIVA GIS, n.d.)

Figure 8:
Flood risk map based on the Flood hazard, – exposure, – vulnerability maps (Generated in QGIS. – Data sources: DIVA GIS (n.d.), UGSG (n.d.) Copernicus Sentinel data 2018, ESA. GeoNode (n.d.), SEDAC (n.d.), Open Development Cambodia (n.d.), Google Maps, OpenStreetMaps)

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Table 1:
Calibration results of parametres in SWMM

Table 2:
LID (green infrastructure) flood mitigation effect of typical rainfall event

Figure 1:
Study area and the urbanisation progress through Google Earth (Image: Landsat/Copernicus) (Red river flows through the middle of the city which has been protected with dike system) (adapt from Kefi et al,) (Kefi et al., 2018).
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Figure 2:
Delineation of the case study area in SWMM model: The boundary of the study area

Figure 3:
Delineation of the case study area in SWMM model: Delineation of catchment area based on the topology, the location of manholes and sewer network in SWMM model (red circle is the simulation note for calibration between observed and simulated flood event)

Figure 4:
Validation for rainfall induced flooding event (May 11, 2021)