

Exploring community perceptions and engagement of nature-based solutions: The case of Ningbo, a Chinese coastal sponge city

*Original*

Exploring community perceptions and engagement of nature-based solutions: The case of Ningbo, a Chinese coastal sponge city / Ka Shun Chan, Faith; Lu, Lingwen; Zhu, Yafeng; Balzan, Mario V.; Pezzoli, Alessandro; Johnson, Matthew; Zhu, Fangfang; Ruan, Tian; Luo, Gang; Li, Gang; Xu, Yaoyang. - In: NATURE-BASED SOLUTIONS. - ISSN 2772-4115. - 4:(2023), pp. 1-14. [10.1016/j.nbsj.2023.100093]

*Availability:*

This version is available at: 11583/2982775 since: 2023-10-05T13:21:16Z

*Publisher:*

Elsevier

*Published*

DOI:10.1016/j.nbsj.2023.100093

*Terms of use:*

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

*Publisher copyright*

(Article begins on next page)



# Exploring community perceptions and engagement of nature-based solutions: The case of Ningbo, a Chinese coastal sponge city

Faith Ka Shun Chan<sup>a,b,\*</sup>, Lingwen Lu<sup>a,c,e,\*</sup>, Yafeng Zhu<sup>a,f,\*</sup>, Mario V. Balzan<sup>d</sup>,  
Alessandro Pezzoli<sup>e</sup>, Matthew Johnson<sup>f</sup>, Fangfang Zhu<sup>g</sup>, Tian Ruan<sup>c</sup>, Gang Luo<sup>c</sup>, Gang Li<sup>c</sup>,  
Yaoyang Xu<sup>c,\*</sup>

<sup>a</sup> School of Geographical Sciences, Faculty of Science and Engineering, University of Nottingham Ningbo China, Ningbo 315100, China

<sup>b</sup> Water@Leeds Research Institute, University of Leeds, Leeds LS2 9JT, United Kingdom

<sup>c</sup> CAS Key Laboratory of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, 1799 Jimei Road, Xiamen 361021, China

<sup>d</sup> Institute of Applied Sciences, Malta College of Arts, Science and Technology, Paola, Malta

<sup>e</sup> DIST, Politecnico and Università degli Studi di Torino, Viale Mattioli 39, 10125 Torino, Italy

<sup>f</sup> School of Geography, University of Nottingham, Nottinghamshire, NG7 2RD, United Kingdom

<sup>g</sup> Department of Civil Engineering, Faculty of Science and Engineering, University of Nottingham Ningbo China, Ningbo 315100, China

## ARTICLE INFO

### Keywords:

Nature-based solutions  
Sponge city  
Landscape appreciation  
Environmental learning

## ABSTRACT

Sustainable stormwater management facilities such as strip bioretention, effectively improve the urban landscape's urban stormwater quality and aesthetics. The progress of Nature-Based Solutions (NBS) and Blue-Green Developments such as the Sponge City Program (SCP) in Chinese cities, is significantly delivering multiple benefits to address urban water, climate and ecosystem services. These practices are transforming the urban environmental context and enhancing the wider aspects of social-environmental interactions and participation. This study will particularly focus on investigating the SCP practices implemented for several years in Ningbo, a selected Sponge pilot city on the east coast of China. There is currently a lack of substantial findings from the perspective of communities towards NBS in China or an understanding of the importance of participation and engagement processes in Sponge or NBS infrastructure in Chinese cities. Through an in-depth semi-structured interview ( $n = 34$ ), this study will elucidate the previous developments, current challenges and future delivery of constructed NBS infrastructure (e.g. artificial wetland). This article will undertake a detailed investigation of public perceptions, channels of learning, and opportunities for further participation and engagement in the case of Ningbo. In this study, we found that the perception and participation are likely to improve significantly in the future and that public education about SCP practices would foster closer human-nature stormwater connections and co-production to deliver better NBS practices.

## 1. Introduction

### 1.1. Nature-based solutions (NBS) and sponge city program (SCP)

China has the most rapid urbanisation in the world, with a more than 64 % urbanisation rate on average across the nation, which is considerably higher than the national growth rate of 45.9 % [7]. The rapid growth of the urban population in China has led to urban environments (i.e. cities) representing dense and often disorderly sprawls of the built environment, with largely degraded urban ecosystem services and

detrimental impacts on the health (mental and physical) of residents [11], and their social well-being [17].

The concept of NBS has evolved into an umbrella concept, which incorporates concepts such as Blue-Green Infrastructure (BGI), ecosystem approach, and ecosystem services. It provides a new perspective for creating a revitalized and restored urban environment [30], which includes the revitalization and restoration of urban green infrastructure (i.e. retrofits in the old districts) [19]. NBS can effectively address multiple benefits, including improved social well-being and sustainability in resource use. At its core, NBS focus on the overall theme

\* Corresponding authors.

E-mail addresses: [faith.chan@nottingham.edu.cn](mailto:faith.chan@nottingham.edu.cn) (F.K.S. Chan), [Lingwen.Lu2@nottingham.edu.cn](mailto:Lingwen.Lu2@nottingham.edu.cn) (L. Lu), [ssyyz8@nottingham.ac.uk](mailto:ssyyz8@nottingham.ac.uk) (Y. Zhu), [yyxu@iue.ac.cn](mailto:yyxu@iue.ac.cn) (Y. Xu).

<https://doi.org/10.1016/j.nbsj.2023.100093>

Received 17 December 2022; Received in revised form 18 August 2023; Accepted 22 September 2023

Available online 26 September 2023

2772-4115/© 2023 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

of learning and using nature to create a sustainable social ecosystem and improve human well-being [18].

In China, the Central National Government (CNG) recognised these benefits and initiated the “Sponge City Program” (SCP) in 2013, which seeks to integrate the National campaign of promoting “ecological civilization” and the green movement in the urban context that is similar to the context of NBS but running in the Chinese planning practice and jurisdiction [46]. The CNG targeted to solve urban stormwater problems (i.e. urban surface floods and stormwater pollution control, etc.) through the implementation of BGI rather than only relying on conventional “grey” drainage infrastructure. The SCP development is not only promoting traditional urban greenery solutions (e.g. urban parks, urban forests, etc.). This delivers multiple benefits, combining the “blue” (e.g. ponds and wetlands) and “green” (e.g. swales and rain gardens, etc.) with bio-retention functions [48], which can purify and mitigate urban stormwater pollution and enhance more resilient water storage for floods and droughts remediation in all seasons. Over the last 8 years, the SCP has gradually transformed the selected 30 pilots into “Sponge Cities”. The SCP integrates blue and green spaces to enhance urban liveability, resilience and sustainability in old districts (old towns) and new development districts (new towns).

Bioretention infrastructure (e.g. artificial ponds and wetlands, floating islands, etc.) [12] has been widely used in Chinese sponge cities. For example, in Cicheng, an old district of Ningbo, an artificial wetland park was built in the residential area, which effectively treats local urban stormwater pollution (i.e. Suspended Solids, Nitrogen, Phosphorus, etc.) [2], through substantial reedbeds and local water grasses and perennials. It also provides substantial water storage spaces for urban stormwater runoff [40]. The wetland park is used as a sports running trail and kids’ playground that delivers multiple benefits and promotes public participation and engagement [16]. The importance and function of bioretention infrastructure in newly built environments can significantly improve existing urban stormwater management practices by reducing urban runoff and peak discharge, and re-enhancement of the urban hydrological cycle [39].

## 1.2. SCP and public participation

In highly urbanised Chinese cities, the establishment of SCP has undoubtedly enhanced multiple benefits [8]. Currently, there is a lack of understanding of the social perceptions and public engagement with the NBS/SCP infrastructure in these new-created ecosystems [17]. However, community engagement and participation are critical to the uptake and continued development of BGI implementation [5]. To successfully produce sustainable solutions to pervasive urban hydrological problems, better support and involvement for existing NBS and BGI developments are needed. The public perception and understanding of the utility and functions of urban green infrastructure (e.g. NBS, BGI, SCP, etc.) have been the focus of recent studies in Western countries (e.g. EU, Norway, US, UK, etc.) [10,23,29].

These studies indicate that an improvement in local community perceptions of NBS and BGI is directly linked to the community’s participation in these practices, which increases their concerns, engagement and involvement in future activity and management strategies (e.g. maintenance and further development of the green infrastructures [14,15]. Positive community perceptions and engagement with NBS will improve the potential for upscaling co-production, co-maintenance and citizen science activities, widely documented in the European Union (e.g. the case in the Netherlands, United Kingdom and E Europe) and North America (e.g. Portland and Seattle in the NW United States) [4,13,36].

Whilst much is known from communities in Europe and North America, little work has been performed on community perceptions and engagement of NBS approaches in China, despite the rapid and widespread application of such approaches nationally. China is yet to be the focus of an in-depth study of community perception, participation and

social benefits of urban sustainable stormwater management solutions in the planning process. Although bioretention structures have been widely used in Chinese cities, there is a lack of substantive information about stormwater quality improvement or landscape aesthetic implications from a community perspective, and more importantly, a lack of understanding of the involvement and process of participation in bioretention, but also for other BGI infrastructures [44].

This study aims to investigate the public interactions between communities in the newly built and created bioretention infrastructure via a case study in Ningbo with three SCP sites (Cicheng, New East Town and Meishan). Several specific research objectives need to be achieved for the research aim, as follows:

- 1 To investigate the residents’ perceptions and participation in bioretention as NBS infrastructure or SCP practice;
- 2 To investigate the caveats and challenges of NBS/ SCP Bioretention infrastructure and its implementation and maintenance (from stakeholders and communities);
- 3 To compare the differences between the public’s perception and participation in the old town and the newly built urban environment (new town) in the case of Ningbo;
- 4 To discuss the current challenges and future NBS (SCP) development and better delivery of the BGI

In the above literature review and background study, which has been explicitly digested through a systematic analysis (see Table 1 below) with the present the scientific novelty such as the gaps identified, the novel contributions for the above references cited and the connections to the research aim and objectives (with the research questions) in this investigation.

## 2. Methods

This study has followed the steps as initiated from the literature review for understanding the background and the connections with the research aim and objectives (see Section 1 and Table 1). Afterwards, this research adopted the “case study” and the location we have selected in Ningbo with three various Sponge City Program implemented locations (i.e. Cicheng, New East Town and Meishan).

We further adopted the methods by using semi-structured interviews to collect the data. We extract the results through the coding framework for the data analyses, then finalise the research findings and provide the future recommendations of this study and illustrated by the applied scientific methods flow chart (see Fig. 1 below). We will also explain all methods (i.e. case descriptions) and approaches (i.e. semi-structured interviews scope and the coding pattern) in detail in the sub-Sections 2.1 and 2.2 as follows.

### 2.1. Case study

#### 2.1.1. Background information

Ningbo is a sub-provincial division in northeast Zhejiang Province in China which is of similar status to a prefecture-level city governed by Zhejiang Province but administrated economically and in law directly by the central government of China. In this study, we plan to use three areas in Ningbo City as the study areas (see Fig. 2).

The areas of Cicheng and New East Town have SC facilities, while Meishan is an area that has not been developed with the standard of SC construction. Secondly, according to 2021 statistics from the local government, the population density of Cicheng and New East Town is 565 people/km<sup>2</sup> and 12,618 people/km<sup>2</sup>, respectively, while the population density of Meishan is 304 people/km<sup>2</sup>. Thirdly, the Cicheng and New East Town are inland, and Meishan Island is in the coastal area. These three districts in Ningbo City will be used to identify comprehensive urban stormwater runoff characteristics and GI effectiveness, and the characteristics are described as follows:

**Table 1**

Digest of the literature review in this study.

Categories in the literature review	Gaps identified	Scientific motivations	Connections with the research objectives of this study	Literature and references
<b>1.1 Connections of NBS &amp; SCP</b>	- Elucidate the urbanisation rate in the Chinese cities are increasing and deteriorating the urban environments - Identified the concept of the NBS	- Provide incentives for improving the urban ecosystems  - Provide the illustration that the NBS delivers multiple benefits including social well-being and sustainability	- Understanding the background of the current progress of SCP across the Chinese cities - connect with the research objective 1  - Understanding the core value and concepts of the NBS - connect with the research objective 1	[7,11,17]  [18,19,30]
	- Illustrated the concept of “SCP” explicitly	- Indicate that the initiation and progress of the SCP - identify the functions and purpose of SCP in China	- Understanding the concept, practices and progress of the SCP e.g. the National Government selected 30 Pilot Sponge Cities to encounter the practice - connect with the research objectives 1–2	[46]; Liang et al., 2020; [48]; Chan et al., 2021
	- Demonstrate the current practices and examples of the SCP	- illustrate the practices such as bio-retention infrastructures and show how the SCP works in the Sponge Cities	- Opening up the story on necessities for public engagement (e.g. park users and their participation – in sports running trails) - Connect with the research objectives 1–3	[12,16,39,40]
<b>1.2 Current Progress and Participation of the SCP</b>	- Illustrate the importance of public participation by the EU experiences	- Perception and understandings are the key to improving public participation	- Responding to the objectives of this study such as the importance to understand the perceptions and participation in the SCP - Connect with the research objectives 1–3	[5,8,10,17,23,29]
	- Demonstrate that participation is the key to delivering better NBS worldwide	- Participation and engagement can help a better delivery (e.g. co-production, citizen science activities)	- Responding to the objectives that show the NBS/SCP practices on the implementation and maintenance - Connect with the research objective 2–4	[4,13–15,36]
	- Provide the argument and caveat to enhance public perception and participation in the SCP in Chinese cities	- Showing the gaps that the current participation is not fully understood	- Connect the argument about the public perception and participation in the case of Ningbo and discuss the current and future SCP development in the Chinese cities - Connect with the research objectives 1–4	[44]

### 2.1.2. Meteorological conditions

Ningbo belongs to the subtropical monsoon climate zone. The rainfall is mostly concentrated from June to July, including typhoon seasons. The average annual rainfall is 1457 mm, of which the total rainfall from May to September accounts for about 65.6 % of the annual rainfall. The impact of rainfall can easily lead to the triple impact of “flooding, waterlogging and tide” in the city. Through an analysis of 5367 days of rainfall data for the 35 years between 1981 and 2015, the design rainfall corresponding to 80 % of the total annual runoff control rate in Ningbo is 24.7 mm. For example, during typhoon periods; for example, Muifa on 13–14th September 2022 recorded over 292.6 mm/24 h at Cicheng (1-in-100 years return period), rainfall far exceeds the limit of SCP construction guidance (at 1-in-30 years return period) [16,17]. As a result, the SCP infrastructure cannot cope with such intensity and runoff capacity and will be inundated (overflowed) (see Fig. 3).

### 2.1.3. Hydro-geographical conditions

Characteristics of the water system and soil. The area is mainly characterized by a floodplain water network, with coastal waters and rivers, low terrain and a dense river network. There are 56 water systems in the research area, typically characterized by low flow velocities and insufficient self-purification capacity. The soil type in the Ningbo pilot areas mainly consists of silty clay. According to the soil permeability test, the permeability coefficient is between 1.2 and  $2 \times 10^{-7}/\text{cm s}^{-1}$ . Therefore, the permeability is poor and it lacks good infiltration ability.

Cicheng is located in the Jiangbei district, which includes Cicheng ancient town area and Cicheng new town area. The 2021 Statistical Yearbook published by the Jiangbei District Bureau of Statistics, indicated that people in Cicheng had a per capita disposable income of 70,464 yuan in 2020. The ancient town's current density is high, mostly key cultural relics in protected areas.

In addition, the greening rate is low and the overall water quality of the hydrological system is poor. Combined sewer overflow pollution is prominent, and there is a water safety problem with waterlogging commonly occurring after rainfall. The SCP construction in this area focused on eliminating or mitigating waterlogging and combined sewer

overflow pollution. The Cicheng new town area is mainly based on contemporary construction with the concept of “water sensitivity” considered at an early stage. However, the existing facilities have been lacking in operation and maintenance for a long time. The construction focus in this area was to upgrade and repair the existing SCP facilities and strengthen the planning and control of new projects.

New East Town, located in the Yinzhou district, is the political, economic, cultural and commercial centre of Ningbo City. The Yinzhou District Bureau of Statistics' 2021 Statistical Yearbook estimated that the urban population in the district occupied a per capita disposable income of 73,860 yuan in 2020. An ecological corridor was established within it that is approximately 3.3 km long from north to south with a total land area of around 1 km<sup>2</sup>. The park wetland is the primary construction component. Importantly, the ecological corridor performs the functions of an urban park, an ecological habitat, and a water purification system. For the first time in China, the development of a new city has received the full attention of National Geographic magazine.

Meishan is located in the east of Ningbo, China, Beilun district, which is part of Ningbo-Zhoushan Port. For a long time, the islanders have grown cotton, rice and a variety of economic crops, and many people rely on fishing and breeding various shallow sea products for a living. Additionally, the region focuses on the development of modern service industries led by international trade, based on port and shipping operations and supported by modern logistics.

The per capita disposable income of people in the district was 62,775 yuan in 2020, according to the Beilun District statistical yearbook in 2021. In Meishan, one of the biggest challenges in this region is the material loading and unloading of dust under international trade, which can create ecological risks for local water sources [25]. To mitigate risks, the local government has set up a construction project named “Blue Bay”. This project aims to purify the water system and construct a resilient water ecosystem combined with both land and sea. The BGI practices mainly include a floating island, a green corridor, and constructed wetland park. Fig. 4 and Table 2 illustrate the intensity of development, topography and land cover as well as implemented the NBS (i.e. the SCP sites in this case study).



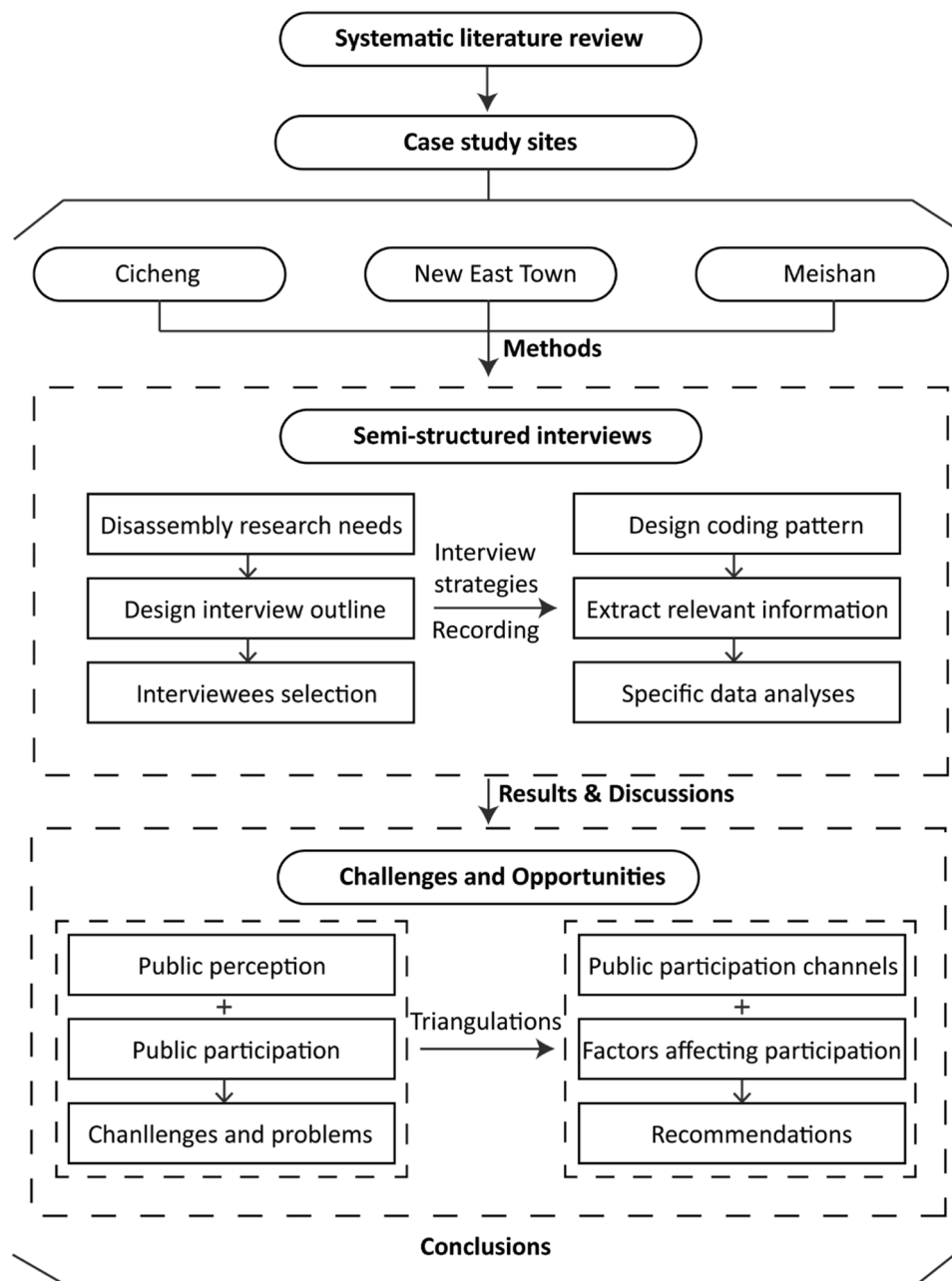


Fig. 1. The flow chart and the steps of the methodology in this study. Source (Lingwen Lu and authors).

## 2.2. Research design – qualitative approach

This study has a case study design [33], which focuses on three SCP sites in Ningbo, connected because they all have recently built NBS urban stormwater designs for improving urban flood resilience, as well as enhancing urban water quality and increasing urban green and blue-green spaces.

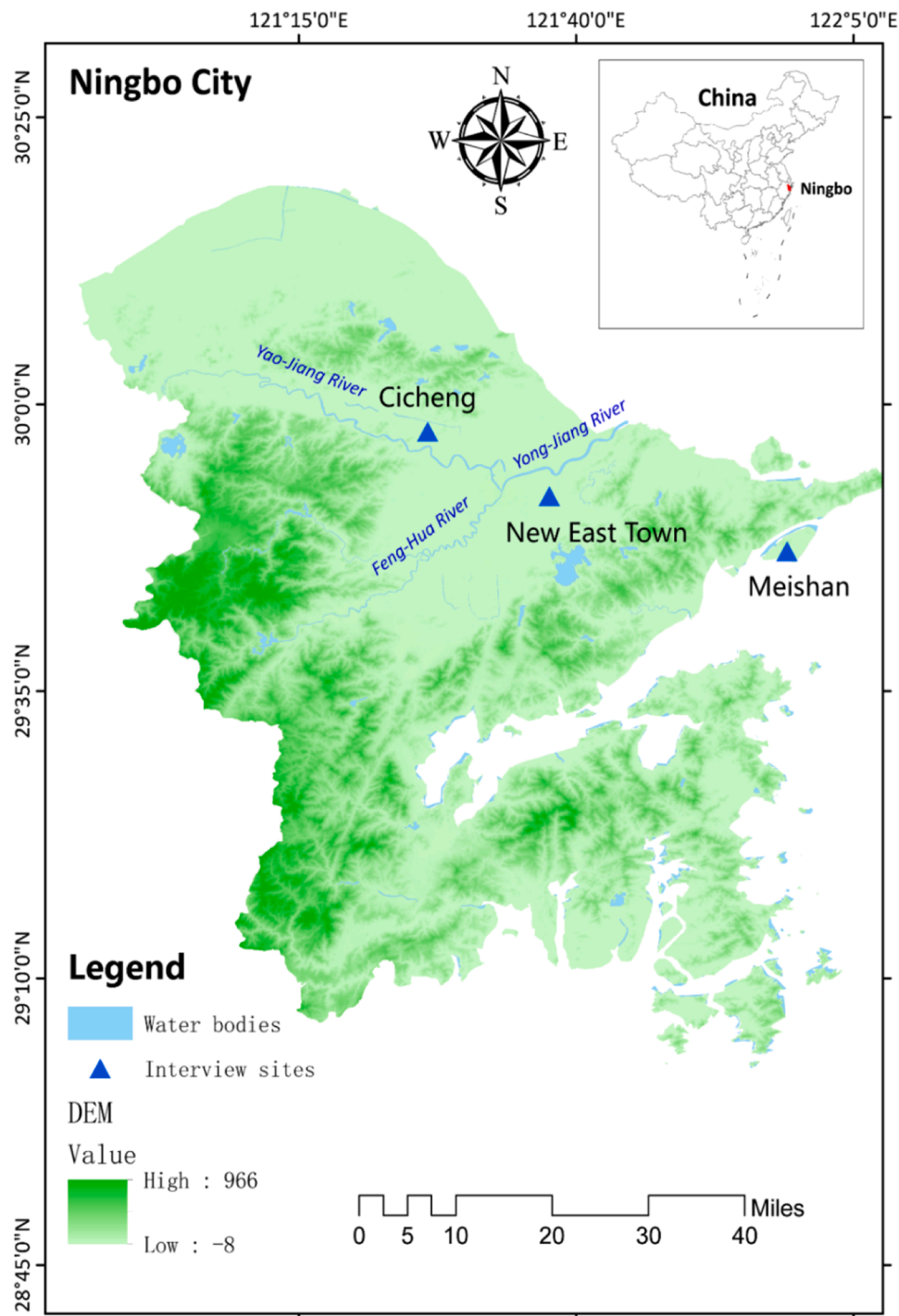
In this study, we obtained information using a qualitative approach using semi-structured interviews (SSIs). Interviews are verbal interchanges where one person, the interviewer, attempts to elicit information from another person. There are three types of interviews: structured, unstructured and semi-structured, which can be placed along a continuum. A structured interview is an interview method with a planned and rigorous set of questions, which means all interviewees get the same questions [35]. We interpret public perception and participation in the three different NBS case study areas in Ningbo, within the

context of the differing hydrogeographical and urban conditions in each. Consistencies and divergences in perception help us understand the current progress and development in engaging local communities in China with the Sponge City Program, as well as the willingness to participate in the program.

### 2.2.1. Semi-structured interviews (SSIs)

The Semi-structured interviews (SSIs) unfolded in a conversational manner offering participants the chance to explore issues that they felt were important. For example, a study from Ireland using a similar qualitative approach performed 35 semi-structured interviews with local communities and stakeholders, to understand the barriers and challenges of tackling urban flooding and climate change.

Here, 34 semi-structured interviews were conducted from July – September 2022 (specific interview questions are shown in Table 3). All information from the participants was anonymised and the average



**Fig. 2.** Research areas with Cicheng, New East Town, and Meishan Island (Source: Lingwen Lu and authors). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

interview time was between 20 and 30 min. Ethics approval was ascertained before interviews and all interviewees were provided with an explanation of the work and a consent form that confirmed their willingness to participate, before taking part. All responses were anonymous and occupation and age were included where respondents chose to provide it. All activities met ethical conduct and all data was stored safely and destroyed after the research project was completed (see Table 4).

#### 2.2.2. Data analyses and coding

For the Cicheng case study, there were 23 interviewees/participants,

except CC014 (SCP Project Engineer) and CC017 (Local Govt. official), the other all 21 interviewees (from CC001–CC013; CC015–016; CC018–CC023) were local residents/communities that live within 3 km of the Cicheng SCP site in the surrounding neighbourhoods (e.g. residential estate). A further 10 interviewees were collected within 3 km of the NBS infrastructure in New East Town (NET) and Meishan (MS). The data was collected during the Summer and Autumn of 2022 (from July – October 2022) with the local communities that are living around the SCP infrastructure, such as the Cicheng Central Lake Park, New East Corridor Sponge Park and the Meishan Sponge Park. We also interviewed various levels of local government officials and Sponge office officials, including



**Fig. 3.** Flood occurrence after typhoon Muifa on 13 September and inundation of the swale. Photo source: Lingwen Lu (approved to use the photos). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

a Sponge Office (SPO) official at the local Sponge City office located in the Ningbo Government Terminal at New East Town, Ningbo, for their viewpoints on current public perception and participation in the SCP.

All data were transcribed and translated from Chinese to English. The transcribed data were analysed by first coding notes and translated transcriptions thematically (see Table 5), followed by tri-angulation to verify whether the interviewee's information was correct using government reports and documents (see Section 4).

### 3. Results

#### 3.1. Public perception of sponge infrastructure

The public was particularly engaged about public policies and practices when they felt that they were included (or at least not excluded) from the decision-making process, similar to results found in the EU and USA where more public engagement during the planning and implementation processes tends to increase public interest [10,32].

##### 3.1.1. Channels of knowledge (communication from the govt/stakeholders)

We explored the channels of knowledge and whether stakeholders and municipality governmental institutions provide suitable communication channels, especially regarding the understanding and perception of the Sponge infrastructure to the public. Interestingly, the communities living at the Cicheng Sponge site had a level of understanding and perception of SCP slightly higher than the other two SCP spots. In this case study, we have found that the responsible authorities have allocated adequate communication channels (e.g. notice boards) and scientific education boards for the residents and public around the Sponge facilities (Fig. 5).

The communities at Cicheng were willing to engage with the available information about the Sponge infrastructure and actively read notice boards. One community resident at Cicheng stated (CC006):

*"...There are notice boards by the roadside, showing the cross-section of the sponge city infrastructure."*

Another three residents at Cicheng also mentioned the governmental bureau had been informative in illustrating the latest Sponge construction and maintenance, providing updates to the residents and communities and stated (CC007, CC015, CC016):

*"...there is a notice board with the schematic diagram of Cicheng Sponge Park inside the park (CC007)"; "...I know the (SCP) concept, as there are the Sponge facilities at the entrance of the park (CC015)"; "...there is a related notice board in the park".*

The information provided by the authorities to the communities about the concepts and functions of SCP in their district(s) focused on the stormwater protection standard and alleviation of urban surface flooding. The information also included the types of Sponge infrastructure, such as the introduction of the functions on permeable pavements, rain gardens, swales, artificial ponds and wetlands, to provide the public with a more comprehensive knowledge of the SCP practices.

##### 3.1.2. Public's understanding and perception of the sponge infrastructure

In this study, we found that the perceptions of the SCP and Sponge infrastructure vary across the study sites (i.e. Cicheng and Meishan). This could be related to the communities and residents' understanding of the infrastructure and the functions of the SCP and the according facilities. For example, in Cicheng, one resident expressed a good





**Fig. 4.** The study sites top: Cicheng, middle: New East Toan, bottom: Meishan in Ningbo (Source: Lingwen Lu, Yafeng Zhu and authors). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

**Table 2**

Comparison of key Information in the interview sites based on the local government Statistical Yearbook in 2020 and relevant previous studies.

Sites\key information	Population	GDP per capita (RMB)	Developed areas	Total area	Retention capacity	Runoff coefficient	Flood risk reduction measures	Water quality improvement
Cicheng	60,414	70,464	49.9 %	2.8 km <sup>2</sup>	0.37	0.60 - 0.85	Swales, wetlands, rain garden, green roofs, drainage system (20 year return period)	Meet the National surface water quality standard at Class IV
New East Town	57,722	73,860	47.3 %	15.9 km <sup>2</sup>	0.39	0.45- 0.60	Swales, wetlands, rain garden, drainage system (20 year return period)	Meet the National surface water quality standard at Class IV
Meishan	18,775	62,775	34.4 %	38.3 km <sup>2</sup>	0.49	0.20- 0.45	Swales, wetlands, drainage system (20 year return period)	Meet the National surface water quality standard at Class IV

Notes: Cicheng Town's inhabitants serve as a proxy for Cicheng's overall population. The people living in Yinzhou District's Fuming Town serve as a proxy for the citizens of New East Town. Meishan Town's population serves as a proxy for the Meishan as a whole. The proportion of developed areas and the area of these sites are based on previous publications [26,46,49]. The definition of water quality categories in China is shown in Supporting Information Table S1.

understanding of the concept of the SCP stated here:

"...Yes, I know the SCP is good, not only by myself, everyone who lives in the area understands how good is the Sponge infrastructure, I know the water (stormwater) can be infiltrated on the road surface and convenient for residents to walk after raining..." (CC007).

Another interviewee was also familiar with the SCP improving the urban flood resilience and the stormwater protection standard on urban surface flood alleviation. One interviewee noted: "...I know the SCP is to prevent floods (urban) in the city..." (CC008).

Whist, another community resident in Cicheng expressed understanding that SCP is related to green space and green infrastructure and stated: "...It seems to be at the gate of the community. At the gate of the

community, the ditch and green belt next to it should be part of sponge facilities." (CC017). There was one resident who also expressed the need for current Sponge facilities in the district and stated that they should be improved for withstanding heavy downpours: "...when it rains heavily, the ground is full of excessive water. We also need to wear rain boots to go out..." (CC019).

In contrast, the perception in the other two sites at New East Town (NET) and Meishan was more superficial and lacked a strong understanding of the SCP. For example, the resident at the NET expressed and questioned the SCP here: "Does it improve the ability of infiltration? I know it..." (NET005). At Meishan, one resident expressed understanding that the SCP improves infiltration but wanted stakeholders and government to prioritise developing the local or regional economy over the SCP: "...

**Table 3**

The main topics of interview questions.

Public perception	Do you know the construction of sponge city in Ningbo? Have you heard of concepts like Bioretention facilities, nature-based solutions, etc.?
Public participation	Where did you learn about concepts such as sponge cities, bioretention facilities, and nature-based solutions? Do you or the people around you have the opportunity to participate in the maintenance or management of these infrastructures or the process of construction? Through which channel did you participate? Which channel do you prefer to engage through? Are you willing to participate in the maintenance of the infrastructure in the construction, such as preventing others from deliberately destroying plants in the facility?
Suggestions collection	Do you have advice for the park managers, planners, local governments, and the public on future urban water management and construction?

**Table 4**

Interviewees' personal information (Sum: 34 interviewees; CC001-MS005 indicates the sites and sequence numbers of the interviewees; CC-Cicheng, NET-New East Town, MS-Meishan).

Interviewee	Occupation and characteristics (most people would not share their detailed jobs)
CC01	/
CC002	/
CC003	/
CC004	/
CC005	/
CC006	/
CC007	Retired (worked as a teacher)
CC008	/
CC009	/
CC010	/
CC011	/
CC012	/
CC013	/
CC014	Engineer
CC015	/
CC016	/
CC017	Government official
CC018	/
CC019	Retired
CC020	/
CC021	/
CC022	/
CC023	Retired
NET001	/
NET002	/
NET003	University student
NET004	Sanitation worker
NET005	/
MS001	/
MS002	/
MS003	Teacher
MS004	/
MS005	/
SPO001	SPO engineer

**Table 5**

Coding pattern of this study.

Major themes	Sub-themes
<b>Public Perception</b>	Communication: channels and understanding Challenges and limitations Solutions
<b>Public Participation</b>	Connections with the perception Government channels (for the public to engage) Challenges and limitations Solutions and opportunities

*But I think it is useless, our country focuses too much on the environment. I think we should develop the economy at first...*" (MS002). That could be due to Meishan being a newer development zone and the local district official has not yet promoted the SCP (e.g. locating billboards and notice boards in the areas). As the participant also expressed, *"...I am not satisfied (in general about the SCP in Meishan). I think it is useless for economic development."* (MS002).

### 3.1.3. Identifying the challenges and problems of the SCP by communities?

We identified some current challenges and issues that could be related to the public perceptions of the current SCP developments. For example, residents who do not settle or stay around the Sponge infrastructure (i.e. Cicheng) are comparatively lacking in understanding and knowledge about the Sponge Infrastructure and facilities. Also, they perceive Sponge or SCP information and knowledge as a personal choice. For example, the resident at Cicheng expressed here:

*"...Sorry, I do not notice that (SCP). Perhaps I am only caring about my own life..."* (CC010).

That was a typical answer, representative of urban China where people are busy with their own life due to the huge pressure of the urban living patterns in Chinese cities related to work rate and pressure on income [21]. Another citizen expressed a similar viewpoint: *"...Oh, who pays attention to this? For the public, as long as it does not affect their use of domestic water, many people will not pay attention."* (CC012).

The connection of respondents to the SCP, particularly in terms of where they live relative to the SCP infrastructure, also mattered and two interviewees expressed that if they had not lived/settled around the Sponge sites, they would not care about the program:

*"...I don't know about the SCP, as I live far away from here (Cicheng), I am living in Yunlu Bay (which is more than 10 km from the Cicheng Sponge site) ..."* (CC009).

Another interviewee also expressed that: *"...I'm not people living here. I do not know (about the SCP) ..."* (CC022).

## 3.2. Public participation in co-maintenance and co-monitoring

In this study, we have found that public participation and engagement level in SCP is not high. The municipality government have provided sufficient channels (see Section 4), but the willingness to participate by the public is not strong or proactive. We will illustrate our findings in more detail in the sub-sections below.

### 3.2.1. Connection with the above sub-section (perception)

We found the interviewees typically had no particular interest to participate in the SCP or they had concerns, such as their opinion that government provides no incentive or opportunities; for example, one interviewee directly denied participation and suggested that there are no opportunities given by the Government: *"No, I do not want to participate the SCP due to lacking opportunities..."* (CC001).

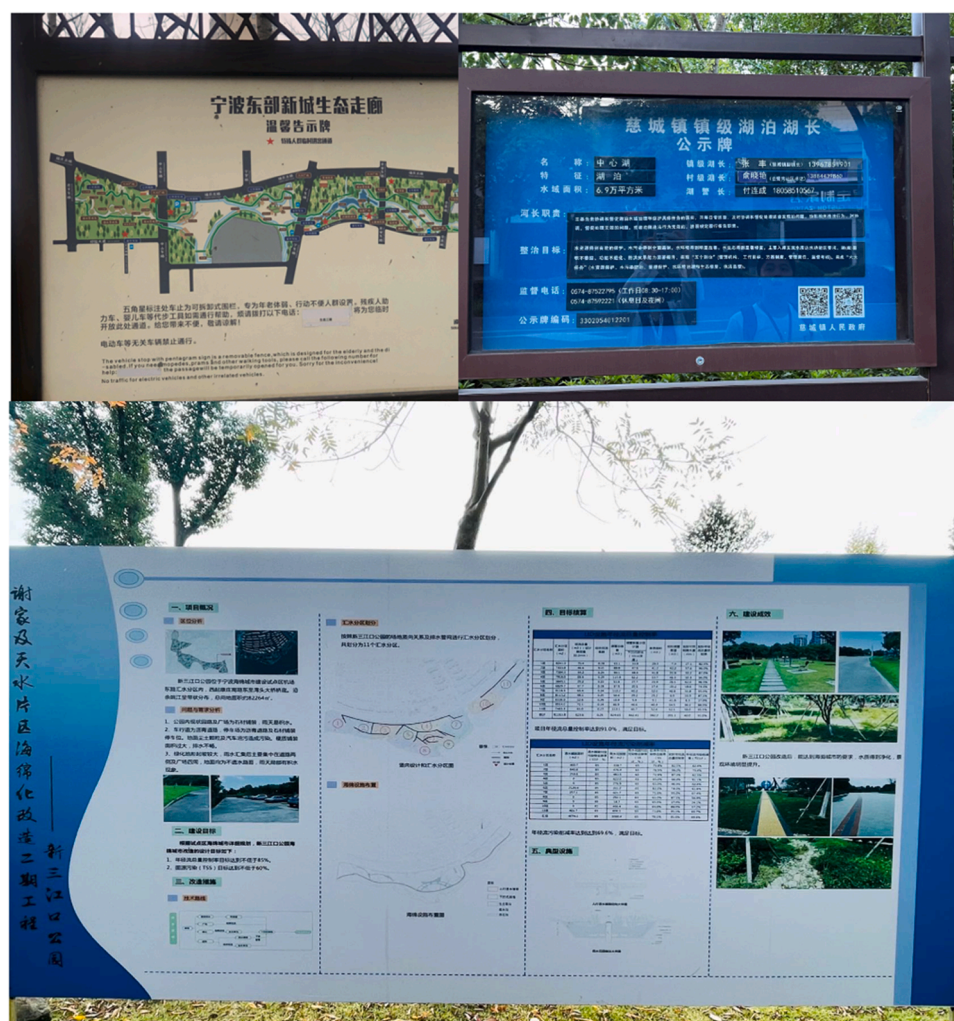
The residents (at Cicheng) also indicated that their perceptions are only expressed when the government invites public consultation meetings of the SCP. One resident said about public consultations:

*"...Rarely, the community sometimes asks us to make suggestions. It is too formalistic. If you provide good suggestions, it will be reported; if they are not satisfied with your advice, they will deal with it..."* (CC003).

Another resident also suggested that the Governmental projects are only planned by the officials and the public is not influenced or interacted with, during the Master Planning process as stated here:

*"...our community don does not seem to play a role in the construction of SCP. This is planned only by the government and is not affected by the public."* (CC007). One resident also does not notice and understand that the government has enhanced the public engagement activities





**Fig. 5.** The Notice board of the SCP facilities and information (top left: Cicheng; top right: NET; bottom SCP functions and construction design in Ningbo City Centre – Three Junction area) (Photo sources: Lingwen Lu and Yafeng Zhu). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

in SCP and stated here: “... Are there any regular meetings on the consultation of SCP maintenance, we don't know, I haven't seen it...” (CC017).

We also found that the residents are worried about lacking sufficient knowledge and perceptions of SCP, which reduce their willingness to participate as noted here:

“...We don't have a deep understanding of the concept and related knowledge, so we would not like to take part in these activities. We are not professional.” (CC010).

### 3.2.2. Government support/channels

We also asked the interviewees if the Government provided opportunities for participation in the SCP, and according to the interviewees, the local street offices had provided opportunities:

“...If there are some problems, we can report them to the sectors in the streets and the government, and they will supervise and then solve it (SCP issue).” (CC013).

Another resident also suggested that the Sponge officials have occasionally organised events to listen to the concerns of the community and residents and stated here that normally will invite the whole family to join together:

“Yes, the official will organise the (community consultation) events, we usually participate in this kind of activities with our family.” (CC023).

### 3.2.3. Any challenges and solutions on public participation?

From the public or community perspective, there were some challenges and limitations illustrated by this study, such as busy living patterns. One interviewee expressed neglect to participate due to a busy work pattern here:

“...No, I do not participate, I have to go to work and I am busy...” (CC004).

Another interviewee also expressed that even though the Government officials invited further engagement, lacking time is an issue: “... No (not participate in SCP). Because I do not have time...” (CC005). Another interviewee also responded similarly:

“...No, I am busy with the job (work)...” (CC011). This is understandable because of the significant living pressure, especially in cities such as Ningbo, where pressures of rental (living) mean people must work hard to survive and improve their living quality, as one interviewee responded here: “No (not participate), as I am too busy (on work) ..., I need to work hard to improve my living quality (in Ningbo) ...” (CC014).

This pressure may be related to whether the interviewee is the



property owner or currently is only at the rental stage, with implications for whether they are willing to participate in the SCP. Interestingly, another interviewee expressed: “No (not participate). Because we don’t buy a house here, we rent a house. So overall, I am satisfied with the present situation...” (CC011). Other than the busy living style, the resident trusted the Governmental departments and institutions to deliver good governance and the SCP practice, as expressed here:

“I do not want to participate and do not need to improve the understanding of the latest development of the SCP, as long as the Government does the job well...” (CC015).

## 4. Discussion – triangulations

### 4.1. Public perception, understanding and engagement

#### 4.1.1. Via social media

In this study, we found that the government and institutions have invested in efforts to communicate via social media platforms such as “Tiktok, WeChat (video channels), and Bilibili (Chinese style of YouTube)”. Social media and mobile network technologies and their network coverage in China nowadays are popular and advanced (most cities utilised 5 G mobile networks). These technologies are interactively influencing the perceptions and understanding of urban flood protection and flood risk management in Chinese cities (i.e. Nanjing), as it is an effective way to provide meteorological warnings and information to the public and communities [43].



**Fig. 6.** The social media channels about the SCP in Ningbo (Top Right – Tencent Video); Cicheng Sponge cite introduction (Top Right); Tencent introductory videos about SCP infrastructure (Bottom Left – Tencent Video); The function of grass swale and permeable pavement (Bilibili – online video platform), WeChat official account of the SCP and the 5 Water issues (Bottom Right). Source (Yafeng Zhu and authors). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

For example, during the Typhoon (In-Fa) in July 2021, the influence of social media (and social media-related technological communication channels) boosted the awareness and understanding of the latest flood preparedness and response information from the storm. That has helped the Ningbo municipality government significantly reduce flood impacts due to the improved awareness and understanding of climatic information (i.e. warnings and emergency responses – shelters and relocation information) [9]. From the interviews in this study, the communities have expressed these social media platforms are helpful for them to build knowledge of the background and functions of Sponge facilities, and their contributions to their communities or districts (see Fig. 6). The interviewee from Cicheng expressed here:

*“...I learnt about Sponge Cities and the concepts mainly through social media by “TikTok” ...”* (CC001).

Two other interviewees also expressed that they learned about the Sponge City Program and the concepts via social media channels, online news channels, and mobile phone apps with “WeChat” or “TikTok” videos. They expressed that:

*“...I have learnt the SCP and the concepts via the short videos (from TikTok and WeChat – the online streams (short videos) ...”* (CC018) and *“...I have got in touch of this information via the online video program offered by the CCTV (The Chinese National Broadcast Channel) in the program of “Focus Interview” ...”* (CC020).

Another interviewee from New East Town also expressed that learnt about the SCP knowledge via the internet and expressed: *“...I have got in touch of the SCP knowledge via the online news and so on...”* (NET005).

We found that the Ningbo municipality government has also undertaken several options for the public engagement channels through the latest popular social media platforms, such as WeChat public accounts for information sharing and informing the public and communities of the latest developments (e.g. projects update, new projects tendering, latest changes of the SCP guidelines and Master Plans, etc.). These social media channels are quite popular; for example, there are more than 7000 views on the Tiktok site for the Sponge City Programme (see Fig. 6). The public and communities can also exchange their opinions and feedback through these channels.

#### 4.1.2. Via other channels

We also found that the citizens in Ningbo can engage with the Sponge City Program (SCP) with stakeholders (if they want to) via several options.

Firstly, the public can express their opinions, ideas and issues through the local SCP office. They are open and encourage the public to visit (NGYZ.GOV.CN, 2022). The public can share their thoughts and ask questions related to the SCP planning and construction guidelines, the updated project and co-related information and the maintenance issues. Occasionally, the Sponge City Office in Ningbo organises the Sponge City program working progress meeting and welcome the public and communities to join and engage with the officials so the public can understand the latest development of SCP [50]. The Municipality government and the Sponge City operational office have also been transparent to inform the public to understand who is the officials and their responsibilities in the SCP executive roles. The public can also access the governmental officials and stakeholders of the Sponge City Operation office via a telephone call to express their suggestions and opinions, for example, via calling 12,345 (Ningbo Governmental Hotlines) (NINGBO.TELEPHONE, 2022).

The public can also use the website and get in touch with the latest information on SCP and enhance communication directly with the stakeholders and governmental officials. For example, the Ningbo Water Conservancy Bureau has provided an online channel for the public to participate and liaise feedback to water engineers, which is freely and transparently opened to the public in Ningbo (a city with a population of over 9.6 million); the communities are open using the live chat box for

interactions and conversations with the local officials for urban water and Sponge City Program issues (See Fig. 7) (NINGBO.GOV.CN, 2022).

## 4.2. Other factors that affect their participation

### 4.2.1. Experiences with climate and environmental hazards

The perception of the flood (or climate-related) risk is greatly affected by experiences and emotional factors and is less associated with rational choice [27]. As such, experiencing natural hazards, such as floods, in this case, could be a direct factor influencing the flood risk perception and understanding of people. For example, if the communities have experienced flooding or been impacted by floods, through their personal experience or by living near flooded spots/locations, this could affect their feelings and understandings of hydrologically “hazardous” or “dangerous” conditions [42].

Flooding in Ningbo is mostly located in the low-lying flood-prone areas, especially in the Yuyao and Cicheng districts owing to the geography of these areas leading to higher exposure to fluvial and pluvial flooding. Such flood and climate hazard-related experiences normally change people’s mindsets and attitudes towards floods and climate extremes (and future climate change issues), as understandably if the public has not been influenced by floods, then the level of alertness and preparedness for flooding is lower than those who have experienced floods. An example is that of Southern England after the 2007 winter floods, as these experiences altered the understanding and perceptions of climate and flood risk in affected communities [45].

In this study, the interviews from Cicheng were concerned far more with the SCP and flood mitigation measures and practices than other regions, but we have found that the communities have gained adequate knowledge. It translates that the personal experience of residents in this area has affected their attitude towards SCP policies and involvement [28]. This is also related to the willingness to be involved in, and participate in, the SCP process [31].

This study suggests that experience has directly influenced the perception and understanding, and willingness to understand, the SCP and their functions in China. That said, the findings also suggest that through the case of Ningbo on the SCP infrastructure as currently not all



Fig. 7. . The Website for the public to participate of Ningbo 5 Water Bureau (Source: Yafeng Zhu).

districts adopted the Sponge facilities in Ningbo. We can argue that for the Cicheng site location, even the SCP practices (swales, artificial wetland, Sponge parks, etc.) have been implemented well there. However, because the intensive rainstorms or typhoon-enhanced storms have frequently occurred and the extreme weather overwhelmed the sponge facility, which has influenced the public's perception of the sponge functions, influenced their willingness and lessened their motives to learn and engage with the SCP practice. As a result, the communities are not too keen on getting updated information on SCP practices from the local government.

This is not affected by the communication, marketing and educational material provided by the municipal government and the sponge city construction and operation office, as we have found all sites have substantial educational components (i.e. notice board, WeChat account, Weibo account, telephone hotline) and the sponge city office allows the public to share their opinions and viewpoints as that means the communication channels for participation are located and implemented quite well.

Public and community engagement in the SCP and urban flood-related practices is important for delivering sustainability and success and, as such, we suggest more attention should be given to the Cicheng site. Likewise, we found that the Ningbo Municipal Government has produced a substantial advertisement campaign on managing urban water and SCP promotion (i.e. the notice board and using bus advertisements to promote these issues), discussed in Section 4.1 (see Fig. 6). The perceptions and understanding that affect public willingness to participate and that is because of their personal experiences with the consequences of flood and climate change in general.

Poussin et al. [34] found that experiences that include visual effects can affect public perception and participation and awareness; for example, educating people as to the kinds of preventive action that can minimise their risks. This is also related to how much people will collaborate and co-produce with the local authorities and stakeholders, working together on the flood management practices, such as emergency drills and cooperation when floods arrive. Chan et al. [6] illustrated that in the case of Tai O town, Hong Kong, the communities were fully committed to the government on flood response and emergency services due to their experience and understanding of the natural hazards, including meteorological scientific knowledge, such as surge heights and tidal effects.

The communities were also aware that the NGB government has enhanced SCP practices to alleviate the hazards, which was appreciated and provided incentives for the public to engage in reducing their possible flood damage as households more fully understood the risk and impacts of flooding in high-exposure areas, including reducing the chance of injuries and damage to property and personal household's assets (e.g. vehicles). Similar findings were found in Shanghai (the city just opposite Ningbo on the E Coast of China that faces similar meteorological conditions on typhoons and storms) [47].

#### 4.2.2. Behaviour, attitude and life patterns (work and norms)

We emphasise that public participation in SCP and urban flood-related practices is highly dependent on individual decisions and behaviours [3]. We understand that if communities face flood experiences or even only witness visual effects, this will typically affect their mental health and future decisions regarding their level of participation in the flood risk management programs, such as in the EU [22]. A similar finding from the UK illustrated that public perception and participation in climate change is subjected related to psychological distance (e.g. their perception and scepticism or perspectives to climate change) and that when the public understands more about climate change, their concern and likelihood to take action is increased [38].

In this study, we have found a similar phenomenon for the public in Ningbo. For local communities to increase their engagement and participation in SCP will likely require a change in their behaviour; however, this, in turn, is governed by the psychological condition and

perceptions of individuals, which are complex and will also affect how people react to governmental flood and climate policies [37]. For instance, we recognised that the public in Ningbo (and other Chinese cities) have a stressful living pattern with pressure on financial income and earnings, and it is normal for the public to trust the local and national government on major projects (e.g. big constructions schemes, and related Environmental impact assessment schemes) [24].

The communities across the three sites had different income classes, but we have found similar findings from across those classes, with people typically not concerned about understanding or engaging with the SCP. In all areas, there was complete trust in the government planning and delivery of infrastructure including the SCP in Ningbo, and they expressed that they are too busy to have time to be concerned about being involved in PP for SCP.

In fact, according to the latest Governmental published enactment on the "Ningbo Water Security of 14th Five-Year Plan" (In Chinese: 宁波市水安全保障“十四五”规划) on 30th June 2021, the Municipality Government stated explicitly "Strengthen publicity and education, improve the public opinion-orientated role of mainstream news media, and improve the public's understanding of the basic situation of water resources in our city." (translated quote from the document) (NINGBO.GOV.CN, 2021)

The commitment to enhancing better public perception and participation was ensured by the official from SPO here:

*"...Ningbo has done a lot on the advertisement and we are very hoping the public to perceive better messages of SCP. As the official has also expressed future foresight and recommendations on improving the perceptions and participation, which is trusting the education and collaboration with the high schools and universities in the city. He expressed here: "We are fully understanding the public to understand more and they will engage with the program better. We suggested that education and promotion are important, for example, to collaborate with the higher education institutions to promote the SCP..." (SPO001).*

These findings show the government is committed and encourages public engagement and participation, hoping that they can perceive the "right" message from stakeholders on SCP design, functions and maintenance related to water and environmental aspects. This makes sense as, through the triangulation of the related policies of the current SCP, the local government has not forced the public/communities to participate with the top-down approach, rather providing freedom of their choice to express their opinions, as mentioned above. The behavioural change is certainly related to their view of environmental and climate motives.

## 5. Conclusion

In this study, we found that the NGB government has put significant effort into the promotion and education of communities to encourage their engagement and support for the SCP. However, engagement is dependent on individual self-interest and perceptions based on external forces and, therefore, participation currently remains low. Key reasons are that people completely trust the Government and so felt their involvement was not needed, and that they were too busy due to financial pressure, to be involved in such schemes.

This study is significant as there are not many studies including the public perceptions and participations of the SCP so far, which remain not too understood from the current literature. In this study, we have adopted the case study approach and used Semi-structured interviews ( $n = 34$ ), with a decent amount of interviews. The number of respondents and interviews are benchmarked by the significant quantities of interviews such as the similar study of NBS and public participation in South Africa and E Europe from Tozer et al. [41] ( $n = 34$ ), and the public perceptions to flood risk management practice in Ireland from Jeffers [20] ( $n = 35$ ). The main purpose was targeted to understand in-depth issues what are the current status of the public perceptions and participation in the Sponge City in the case of Ningbo.



The key finding of this study is that the extent of public participation differs between the modes of decision-making, implementation, maintenance and future developments, which implied the local government (i.e. SPO) has already initiated the channels (e.g. via Sponge office help desk, social media platforms – WeChat and Internet service page chat-box, etc.). Current strategy development for the SCP still relies primarily on the local government. That said top-down decision-making is still actual practice as well as the norm. The public (communities) has gotten used to following the government's policies and practices and trusts the government's decision on promoting and implementing the SCP. Such social norm is quite different from Western countries.

Increasing community engagement in the SCP in China is likely to require incentivizing participation and is less likely to be related to a pro-environmental mindset and behaviour, based on the findings described above. However, by changing public behaviour and boosting participation in the SCP scheme this way will not necessarily mean that the communities will promote broader environmental goals or improve their environmental capitals/Green capitals, or affect how they perceive the SCP campaign [1].

Lastly, we encourage the municipality government and its institutions to keep improving the publicity of SCP, particularly utilising the latest trends and directions in communication, such as via social media and mobile technologies. We also recommend the government to promote and advertise SCP beyond the Sponge surrounding areas, and to expand towards the whole municipality districts because that can allow more communities to understand the program, including communities before implementation. The SCP (in Ningbo and all assigned Sponge Cities) states that c.70 % of city regions should have sponge infrastructure by 2030s according to the municipality districts, and this can enhance co-benefits to promote the program and gain more support from the Public.

### Author contributions

FKSC is the lead author and contributed equally to designing, supervising, writing, and LL and YZ are being responsible for all figures and contributed to the editing, graphic design, and information collection. All other authors discussed, reviewed, and edited the manuscript.

### Declaration of Competing Interest

The authors declare that they have no conflicts of interest.

### Data availability

Data will be made available on request.

### Acknowledgements

This research is supported by the National Key R&D Program of China, Grant/Award Number National Key R&D Program of China (2021YFE0193100; 2019YFC1510400), and the Hong Kong Environmental Council Fund (ECF: 44/2020).

### Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.nbsj.2023.100093](https://doi.org/10.1016/j.nbsj.2023.100093).

### References

- [1] J.C.J.H. Aerts, W.J.W. Botzen, Climate change impacts on pricing long-term flood insurance: a comprehensive study for the Netherlands, *Glob. Environ. Change* 21 (2011) 1045–1060.
- [2] R. Aryal, S. Vigneswaran, J. Kandasamy, R. Naidu, Urban stormwater quality and treatment, *Korean J. Chem. Eng.* 27 (2010) 1343–1359.
- [3] S. Birkholz, M. Muro, P. Jeffrey, H.M. Smith, Rethinking the relationship between flood risk perception and flood management, *Sci. Total Environ.* 478 (2014) 12–20.
- [4] A. Buijs, R. Hansen, S. Van Der Jagt, B. Ambrose-Oji, B. Elands, E. Lorance-Rall, T. Mattijssen, S. Pauleit, H. Runhaar, A. Stahl Olafsson, M. Steen Møller, Mosaic governance for urban green infrastructure: upscaling active citizenship from a local government perspective, *Urban For. Urban Green.* 40 (2019) 53–62.
- [5] J.M. Chambers, C. Wyborn, M.E. Ryan, R.S. Reid, M. Riechers, A. Serban, N. J. Bennett, C. Cvitanovic, M.E. Fernández-Giménez, K.A. Galvin, B.E. Goldstein, N. L. Klenk, M. Tengö, R. Brennan, J.J. Cockburn, R. Hill, C. Munera, J.L. Nel, H. Österblom, A.T. Bednarek, E.M. Bennett, A. Brandeis, L. Charli-Joseph, P. Chatterton, K. Curran, P. Dumrongrojwathana, A.P. Durán, S.J. Fada, J.-D. Gerber, J.M.H. Green, A.M. Guerrero, T. Haller, A.-I. Horcea-Milcu, B. Leimona, J. Montana, R. Rondeau, M. Spierenburg, P. Steyaert, J.G. Zaehring, R. Gruby, J. Hutton, T. Pickering, Six modes of co-production for sustainability, *Nat. Sustain.* 4 (2021) 983–996.
- [6] F.K.S. Chan, O.A. Adekola, G. Mitchell, A.T. McDonald, Appraising sustainable flood risk management in the Pearl River Delta's coastal megacities: a case study of Hong Kong, China, *J. Water Clim. Change* 4 (2013) 390–409.
- [7] F.K.S. Chan, W.Y. Chen, Y. Sang, Y.D. Chen, W. Huang, W.-Q. Chen, J. Griffiths, J. Li, Y. Peng, X. Cai, J. He, X. Gu, Y. Qi, X. Lu, Y. Xu, Z. Wang, P.Y.K. Chau, M. Tan-Mullins, Y.-G. Zhu, Build in prevention and preparedness to improve climate resilience in coastal cities: lessons from China's GBA, *One Earth* 4 (2021) 1356–1360.
- [8] F.K.S. Chan, J.A. Griffiths, D. Higgitt, S. Xu, F. Zhu, Y.T. Tang, C.R. Thorne, Sponge City" in China—A breakthrough of planning and flood risk management in the urban context, *Land Use Policy* 76 (2018) 772.
- [9] F.K.S. Chan, X. Gu, Y. Qi, D. Thadani, Y.D. Chen, X. Lu, L. Li, J. Griffiths, F. Zhu, J. Li, W.Y. Chen, Lessons learnt from Typhoons Fitow and In-Fa: implications for improving urban flood resilience in Asian Coastal Cities, *Nat. Hazards* (2021).
- [10] M. De Groot, Exploring the relationship between public environmental ethics and river flood policies in western Europe, *J. Environ. Manage.* 93 (2012) 1–9.
- [11] J. Dick, J.D. Miller, J. Carruthers-Jones, A.J. Dobel, S. Carver, A. Garbutt, A. Hester, R. Hails, V. Magreehan, M. Quinn, How are nature based solutions contributing to priority societal challenges surrounding human well-being in the United Kingdom: a systematic map protocol, *Environ. Evid.* 8 (2019) 11.
- [12] M.E. Dietz, Low impact development practices: a review of current research and recommendations for future directions, *Water Air Soil Pollut.* 186 (2007) 351–363.
- [13] G. Everett, O. Adekola, J. Lamond, Developing a blue-green infrastructure (BGI) community engagement framework template, *Urban Des. Int.* (2021).
- [14] G. Everett, J.E. Lamond, A.T. Morzillo, A.M. Matsler, F.K.S. Chan, Delivering Green Streets: an exploration of changing perceptions and behaviours over time around bioswales in Portland, Oregon, *J. Flood Risk Manage.* 11 (2018) S973–S985.
- [15] G. Everett, A.M. Matsler, F.K.S. Chan, M.A. Naclerio, A.T. Morzillo, J.E. Lamond, Lifestyle and language barriers influence community engagement with green infrastructure, *Ambio* (2023).
- [16] J. Griffiths, F.K.S. Chan, M. Shao, F. Zhu, D.L. Higgitt, Interpretation and application of Sponge City guidelines in China, *Philos. Trans. A Math. Phys. Eng. Sci.* 378 (2020), 20190222.
- [17] J.A. Griffiths, F.K.S. Chan, Sustainable Urban Drainage. Reference Module in Earth Systems and Environmental Sciences, Elsevier, 2022.
- [18] N.M. Gulsrud, K. Hertzog, I. Shears, Innovative urban forestry governance in Melbourne?: investigating "green placemaking" as a nature-based solution, *Environ. Res.* 161 (2018) 158–167.
- [19] H.I. Hanson, B. Wickenburg, J. Alkan Olsson, Working on the boundaries—How do science use and interpret the nature-based solution concept? *Land Use Policy* 90 (2020).
- [20] J.M. Jeffers, Double exposures and decision making: adaptation policy and planning in Ireland's coastal cities during a boom—Bust cycle, *Environ. Plan. A: Econ. Space* 45 (2013) 1436–1454.
- [21] E.E. Koks, B. Jongman, T.G. Husby, W.J.W. Botzen, Combining hazard, exposure and social vulnerability to provide lessons for flood risk management, *Environ. Sci. Policy* 47 (2015) 42–52.
- [22] H. Kreibich, I. Seifert, A. Thieken, E. Lindquist, K. Wagner, B. Merz, Recent changes in flood preparedness of private households and businesses in Germany, *Reg. Environ. Change* 11 (2011) 59–71.
- [23] H. Lazrus, R.E. Morss, J.L. Demuth, J.K. Lazo, A. Bostrom, Know What to Do If You Encounter a Flash Flood": mental models analysis for improving flash flood risk communication and public decision making, *Risk Anal.* 36 (2016) 411–427.
- [24] T.H.Y. Li, S. Thomas Ng, M. Skitmore, Public participation in infrastructure and construction projects in China: from an EIA-based to a whole-cycle process, *Habitat Int.* 36 (2012) 47–56.
- [25] J.-C. Liu, X.-H. Li, H.-L. Xu, J.-X. Cheng, Z.-D. Wang, Y. Xiao, Superposition impact character of air pollution from decentralization docks in a freshwater port, *Huanjing Kexue* 34 (2013) 2044–2050.
- [26] M. Liu, To discuss the waterfront plant landscape configuration — taking the "North Area of Eastern New Town ecological corridor" as an example, *Modern Agric. Res.* 29 (2022) 94–97 (in Chinese).
- [27] I. Lorenzoni, A. Leiserowitz, M. Doria, W. Poortinga, N. Pidgeon, J. Risk Res. 9 (2006) 265.
- [28] Lowe, T., Brown, K., Dessai, S., De Franca Doria, M., Haynes, K. & Vincent, K. 2005. *Does tomorrow ever come? Disaster narrative and public perceptions of climate change.*
- [29] P. Lujala, H. Lein, J.K. Rød, Climate change, natural hazards, and risk perception: the role of proximity and personal experience, *Local Environ.* 20 (2015) 489–509.
- [30] J. Maes, S. Jacobs, Nature-based solutions for Europe's sustainable development, *Conserv. Lett.* 10 (2017) 121–124.

- [31] T. Myers, Nat. Clim. Change 3 (2013) 343.
- [32] M.T. Niles, M. Lubell, V.R. Haden, Perceptions and responses to climate policy risks among California farmers, Glob. Environ. Change 23 (2013) 1752–1760.
- [33] Perri & Bellamy, C. 2012. Principles of methodology: research design in social science. London.
- [34] J.K. Poussin, W.J.W. Botzen, J.C.J.H. Aerts, Factors of influence on flood damage mitigation behaviour by households, Environ. Sci. Policy 40 (2014) 69–77.
- [35] Y. Qi, F.K.S. Chan, E.C. O'donnell, M. Feng, Y. Sang, C.R. Thorne, J. Griffiths, L. Liu, S. Liu, C. Zhang, L. Li, D. Thadani, Exploring the development of the Sponge city program (SCP): the case of Gui'an New District, Southwest China, Front. Water 3 (2021).
- [36] T.B. Randrup, A. Buijs, C.C. Konijnendijk, T. Wild, Moving beyond the nature-based solutions discourse: introducing nature-based thinking, Urban Ecosyst. 23 (2020) 919–926.
- [37] J.J. Rouillard, A.D. Reeves, K.V. Heal, T. Ball, The role of public participation in encouraging changes in rural land use to reduce flood risk, Land Use Policy 38 (2014) 637–645.
- [38] A. Spence, W. Poortinga, N. Pidgeon, The psychological distance of climate change, Risk Anal. 32 (2012) 957–972.
- [39] H. Takaijudin, A.A. Ghani, N.A. Zakaria, Challenges and developments of bioretention facilities in treating urban stormwater runoff; A review, Pollution 2 (2016) 489–508.
- [40] R.A. Tirpak, A. Afrooz, R.J. Winston, R. Valenca, K. Schiff, S.K. Mohanty, Conventional and amended bioretention soil media for targeted pollutant treatment: a critical review to guide the state of the practice, Water Res. 189 (2021) 17.
- [41] L. Tozer, K. Hörschelmann, I. Anguelovski, H. Bulkeley, Y. Lazova, Whose city? Whose nature? Towards inclusive nature-based solution governance, Cities 107 (2020), 102892.
- [42] G. Wachinger, Risk Anal. 33 (2013) 1049.
- [43] B. Wang, B. Loo, F. Zhen, G. Xi, Urban resilience from the lens of social media data: responses to urban flooding in Nanjing, China, Cities 106 (2020), 102884.
- [44] Y. Wang, J. Cai, J. Zuo, K. Bartsch, M. Huang, Conflict or consensus? Stakeholders' willingness to participate in China's Sponge City program, Sci. Total Environ. 769 (2021), 145250.
- [45] L. Whitmarsh, Are flood victims more concerned about climate change than other people? The role of direct experience in risk perception and behavioural response, J. Risk Res. 11 (2008) 351–374.
- [46] G. Yang, Y. Jin, Y. Li, Geological suitability evaluation of ningbo meishan island engineering construction based on GIS, Marine Sci. 44 (5) (2020) 133–140 (in Chinese).
- [47] J. Yin, D. Yu, B. Liao, A city-scale assessment of emergency response accessibility to vulnerable populations and facilities under normal and pluvial flood conditions for Shanghai, China, Environ. Plan. B: Urban Anal. City Sci. (2020), 2399808320971304.
- [48] Z. You, L. Zhang, S.-Y. Pan, P.-C. Chiang, S. Pei, S. Zhang, Performance evaluation of modified bioretention systems with alkaline solid wastes for enhanced nutrient removal from stormwater runoff, Water Res. 161 (2019) 61–73.
- [49] W. Zhang, X. Wang, Construction of Cicheng New Town drainage safety system based on Sponge City concept, China Water Wastewater 14 (2020) (in Chinese).
- [50] Zhudingwendao.com, 2022. Ningbo held the Sponge City construction work promotion conference. <http://www.zhudingwendao.com/newsx.php?lm=23&id=1367>.