Exploring the potential of urban nature-based solutions to address infectious disease: a case study in Bharatpur, Nepal

SEI report
February 2025

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Published by

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An open drainage canal in Bharatpur, Nepal. © SEI.

Acknowledgements

The project thanks the Bharatpur Metropolitan City and representatives of wards 2, 10 and 29 for supporting the study. Further thanks to the surveyors: Suvarna Ghimire, Nipesh Nepal, Sagar Joshi, Kajal Adhikari, Sabina Kunwar and Ashika Kunwar. Ethical clearance was granted by the Nepal Health Research Council with reference number 1462.

Pottinger-Glass, C., Ghimire, U., Dotel, S., Rai, A., Tran, M., Green, J., & Barquet, K. (2025). *Exploring the potential of urban nature-based solutions to address infectious disease: a case study in Bharatpur, Nepal*. SEI report. Stockholm Environment Institute.

DOI: https://doi.org/10.51414/sei2025.011

The Youth Innovation Lab (YI-Lab) is a not-for-profit civic tech company that operates at the intersection of cutting-edge technology and its applications, empowering young professionals to tackle emerging challenges in our communities. YI-Lab's mission is to engage young people in bridging science to people and policy through innovation. YI-Lab promotes open data, entrepreneurship, and evidence-based advocacy campaigns by leveraging indigenous knowledge, citizen science approaches, and developing cost-effective technological solutions. The organization provides a conducive environment for young people to co-create inclusive development solutions, with a focus on technology development, disaster risk reduction, climate change, open data, entrepreneurship, data-driven advocacy, youth engagement, and volunteerism.

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Key findings

- **Our survey in Bharatpur, Nepal, found one in five households had been affected in the past five years by the mosquito-borne disease dengue fever (18.4%). Skin infections were the second most reported infectious disease, affecting 11.5% of households. Proximity to garbage disposal sites was found to be associated with incidence of both dengue and skin infections, and lack of adequate sanitation and clean water is a hypothesized driver for skin infections.**
- **Nature-based solutions (NBS) have potential to reduce hazard from infectious disease through filtering water, mitigating flooding and reducing urban temperatures. Local actors participating in our workshops were particularly interested in applying green streets and rainwater harvesting in Bharatpur.**
- **Strengthening solid waste management is recommended as a priority action to reduce hazard from dengue, by increasing collection frequency, and ensuring city-wide provision of municipal collection services. Improving piped water supply to peri-urban areas is recommended as a priority action to improve hygiene, reduce skin infections and address critical health inequities among vulnerable populations.**
- **Our study emphasizes that to improve public health outcomes from infectious disease, NBS cannot substitute for basic urban infrastructure and services.**

Contents

1. Introduction

> *"Continued urbanization is expected to lead to cities becoming epicentres of disease transmission, including vector-borne disease."* (WHO, 2021)

Despite rising threats, there is a limited understanding about drivers of infectious disease in cities, particularly with a changing climate. Global caseload of dengue fever – a vector-borne disease transmitted by mosquitos – has been rising, with the World Health Organization documenting a 10-fold increase between 2000 and 2019 (WHO, 2023). Of this, Asia accounts for over 70% of the worldwide disease burden (WHO, 2022). Cities have become hotspots as the two main dengue vectors of *Aedes aegypti* and *Aedes albopictus* are highly anthropophilic (attracted to humans as a food source) and lay eggs in small bodies of stagnant water such as discarded tyres, open drains and potholes (Colón-González et al., 2021). Meanwhile, many cities in low- and middle-income countries face gaps in essential services, such as access to safe, clean water and sanitation, which increase the risk of water-borne diseases such as diarrhoea, typhoid and cholera.

Nature-based solutions (NBS) continue to draw strong global attention as low-cost, flexible and multifunctional interventions that can support heathier and more liveable cities. A growing body of literature focuses on NBS and their positive impacts on reducing rates of non-communicable diseases; for example, a 2020 review article from Kolokotsa et al. (2020) examined 50 case studies on NBS and health in the urban environment, drawing attention to benefits including lowered stress, improved air quality and thermal comfort. However, this review made no reference to infectious disease, for which evidence is scarce for NBS applications.

Examples of NBS that could reduce hazard from infectious disease include constructed wetlands, which utilize specific aquatic plants for wastewater treatment, and urban greening, which can support natural infiltration of water post-flooding, decreasing pressure on overloaded drainage systems, minimizing contamination from sewer overflow, and decreasing available breeding habitat for dengue-carrying mosquitos. Urban greening measures can also reduce heat island effects, associated with higher incidence of dengue (Manica et al., 2016; Wilke et al., 2017).

However, the relationship between green-blue space and vector-borne disease is complex. Certain types of vegetation and standing water in landscapes can also increase hazards by providing suitable habitat for mosquitos, a critique that has been associated with urban constructed wetlands (Walton et al., 2020). Conversely, evidence has shown that restored urban ecological systems can help to manage mosquito larvae through the provision of natural habitats for predator species such as dragonflies and birds (Troyo et al., 2006).

Given these knowledge gaps, through this project, we sought to investigate the drivers of infectious disease in a developing city context, the differentiated hazards faced by different groups such as Indigenous and peri-urban communities, and the potential of NBS to reduce hazards while providing ecological and social co-benefits.

2. Project methodology

Our project took Nepal's third largest city of Bharatpur in the Chitwan district as a case study. A survey of 288 households was carried out in three selected wards based on random sampling from a total of 46 000 residents. Survey respondents self-identified as 55% men and 45% women. The survey was supplemented by three key informant interviews with ward chairpersons and a focus group discussion with the *Aama Samuha* (Women's Group) of the Chepang Indigenous community. We also consulted with representatives from the Department of Health, Department of Disaster Risk Reduction, and Mayor's Office to understand priority issues.

We conducted statistical analysis for survey results to identify the association and relationship between different socio-economic and biophysical variables and the emerging diseases reported. At a validation workshop held in June 2024 to present results, we gathered the feedback and jointly explored the potential feasibility of different NBS options in the local context.

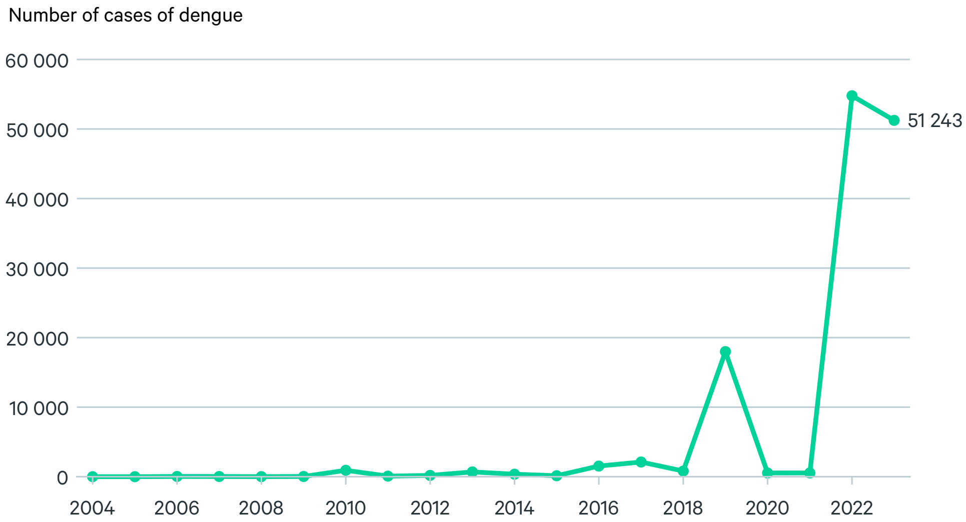
2.1 Study area

Nepal has taken large strides in recent years to improve basic services such as water supply, sanitation and solid waste management, which reduces risk from infectious disease (Overgaard et al., 2021). In 2019, the country achieved coverage of basic household water supply for 91% of the population and sanitation for 99% (NPC, 2020). However, as of 2022, coverage of safe drinking water is only at 23% of the population (WHO and UNICEF, 2022).

Wastewater management remains a pressing concern due to rapid urban population growth and infrastructure deficiencies, meaning untreated wastewater is frequently discharged into water bodies (Karki et al., 2024). These risks are compounded by climate change. For example, in Bharatpur, monsoon flooding combined with inadequate drainage systems and open sewage canals leads to contamination of waterways and shortages of safe drinking water.

Dengue is an increasing public health threat in Nepal, with the largest outbreak to date occurring in in 2022 (Figure 1). There is higher disease prevalence in low-altitude urbanized areas and increased risk associated with higher minimum temperatures during monsoon months (Gyawali et al., 2021). The tropical/subtropical Chitwan Valley, where the city of Bharatpur is located, is a particular dengue hotspot, accounting for 40% of all cases in Nepal from 2010–19 (Gyawali et al., 2021).

Figure 1. Trend of dengue outbreaks in Nepal from 2004–23



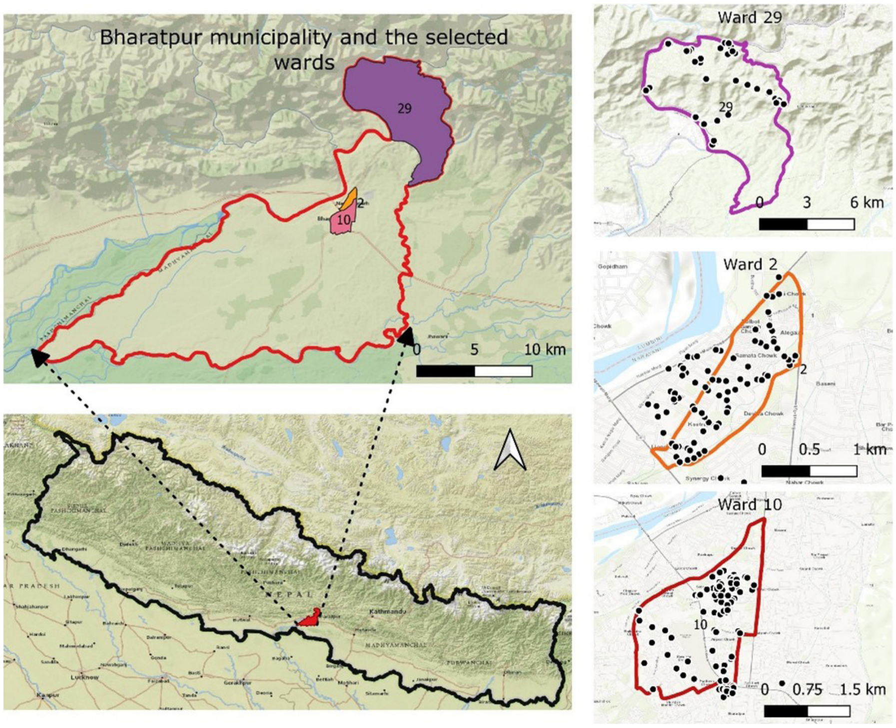
Source: Epidemiology Disease Control Division, Ministry of Health and Population, Government of Nepal; Bharati et al. (2024)

The study focused on 3 of the city's 23 wards for detailed analysis: wards 2, 10 and 29 (Figure 2). These wards were selected based on their differentiated characteristics, as described in Table 1.

Table 1. Characteristics of selected wards

Ward no.	Area (sq.km)	Population (2021)	Characteristics
2	1.33	19 564	Dense, inner city Mostly average income Full provision of basic services (piped water, access to healthcare)
10	4.63	20 633	
29	62.9	5921	Sparsely populated, peri-urban Higher proportion of Indigenous groups Infrastructure and service gaps (poor road infrastructure, lack of piped water) Hilly topography and subject to geophysical hazards: landslides, erosion, flooding

Figure 2. Sampling location of households within selected wards of Bharatpur Metropolitan City



Source: Authors' own

3. Findings: infectious disease incidence and its drivers in Bharatpur

The survey enabled respondents to indicate whether anyone in their household had suffered from certain infectious diseases within the past five years. Diseases which were surveyed aligned with Nepal's Department of Health Servies priority diseases: malaria, kala-azar, dengue, gastroenteritis, cholera and severe acute respiratory infection; also included were scrub typhus and skin infections, which emerged as concerns from consultations with local actors. Disease incidence was tested statistically against potential drivers of hazard using Pearson's Chi-squared test of independence, with two main results: proximity to garbage disposal sites and household reliance on surface water (shown in Table 2).

Table 2. Statistical associations of different drivers of dengue and skin infection

Variable tested	Disease	Result*
Proximity to garbage disposal sites	Dengue and skin infections	*Dengue* X^2 (1, N = 286) = 3.74, p = 0.05 *Skin infections* X^2 (1, N = 286) = 13.88, p = <0.05
Reliance on surface water as household source	Skin infections	*Skin infections* X^2 (1, N = 286) = 35.55, p = <0.05

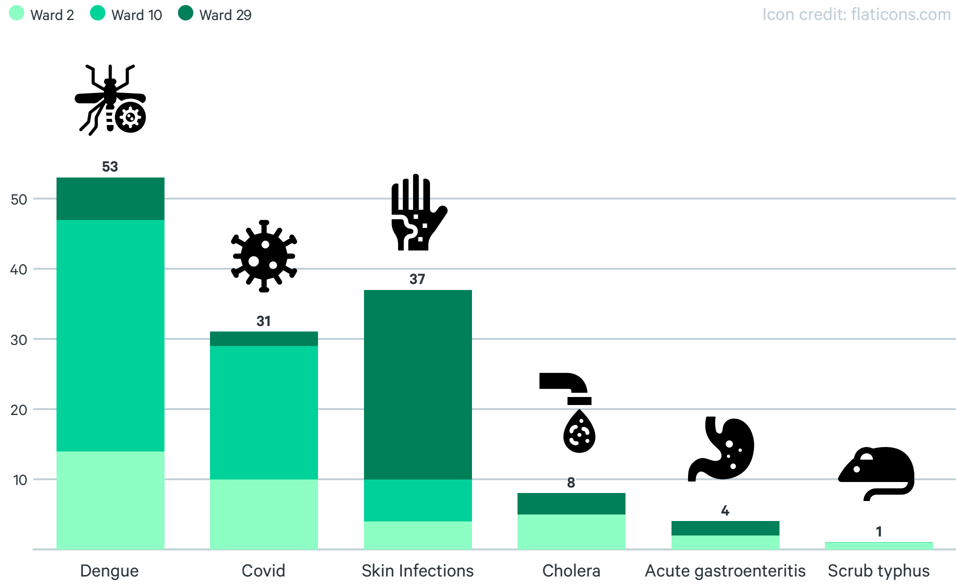
* We report *p*-values here and have not corrected for spatial autocorrelation.

Source: Authors' own

3.1 Dengue

Figure 3 shows household disease incidence in the past five years. Dengue was by far the most prevalent disease, affecting 18% of all 288 surveyed households. In the period surveyed, COVID-19 was second, though it has now reduced substantially.

Figure 3. Household disease incidence in past five years (N = 288)



Source: Authors' own

The worst dengue-affected ward is Ward 10, in which 33% of all sampled households had dengue in the past five years. This is followed by Ward 2 with 14.5% and Ward 29 with 6.2%.

Proximity to garbage disposal sites was found to have a relationship to dengue incidence (Table 2). The survey respondents who resided within 600 m of a garbage disposal site had higher positive cases than others outside this range. This may be due to the conducive environment for mosquito breeding in small pockets of water than can form in human-made containers (see Figure 4). This finding is also consistent with the literature (Aminah et al., 2019; Zolnikov et al., 2023).

Inadequate solid waste management emerged as a key concern among local actors, with infrequent collection, particularly away from main roads where garbage is only collected once a week and the presence of informal waste dumping sites.

As suggested in local consultations and indicated by the results, urban density may be another driving factor for dengue transmission, with disease-carrying mosquitos drawn to inner city areas (wards 2 and 10) as opposed to the peri-urban areas (Ward 29). This is consistent with published scientific literature, which finds a strong relationship between urbanization and prevalence of *Aedes* mosquitos (Kolimenakis et al., 2021).

Proximity to the Narayani River, the main river flowing through the city, was not found to have any association to dengue incidence. However, local actors highlighted the secondary Pungi River as a mosquito breeding hotspot, as it is slow moving due to flatter topography. This river, which flows through Ward 2, has been on the verge of disappearance due to constant influx of sewage and has been prioritized by the municipality for restoration in coming years.

Nearly all – 96% – of survey respondents stated that they had experienced hotter temperatures in the past five years. Households also reported seeing mosquitos even in the winter season, which was previously uncommon, and likely related to this temperature increase.

Figure 4. Observed mosquito breeding site on a disused plot of land

Photo Credit: Youth Innovation Lab

3.2 Skin infections

The number of skin infections in the surveyed households was approximately 11.5% in the past five years. Ward 29 alone accounted for 72% of these cases.

Statistical analysis showed an association of skin conditions with reliance on surface water as a household's principal water source. In Ward 29, 68% of households are reliant on surface water due to lack of adequate piped water. Conversely, no households are reliant on surface water in wards 2 and 10.

Particularly in the summer months, respondents reported outbreaks of skin infections as increased temperatures lead to more perspiration, yet without adequate water to maintain hygiene. Moreover, urban residents reported bathing in polluted river water. Proximity to garbage disposal sites was also associated with skin infections, which may be due to contamination from garbage leachate.

> *"We must travel 2-3 hours to collect drinking water using heavy containers. So, how do you expect us to use that water for bathing?"*
> – representative of Ward 29

Although acute gastroenteritis did not emerge strongly from the survey as a priority condition, this may be due to challenges in understanding the terminology. In a separate long-answer question, where respondents could describe the priority health conditions affecting their community, 19% of respondents from Ward 29 said "gastric conditions", of which contaminated drinking water from inadequate piped water supply is a likely driver.

4. Potential interventions

Local and municipal actors are already undertaking several initiatives to improve the urban environment and reduce health hazards. These include distribution of mosquito nets, school awareness campaigns, and community-led initiatives, including a cleanup campaign for the Pungi River. Independent waste management activities are undertaken by the *Aama Samuha* (Women's Group) of the Chepang Indigenous community in Ward 29, to respond to deficiencies in service provision. Even so, 50% of respondents answered that municipal government and ward-level support to manage infectious disease is "not effective at all".

4.1 Nature-based solutions

Based on our literature review and international and local good practice, we selected certain NBS to be discussed and prioritized by local actors, according to their interest and feasibility. Aligning with the results of the household survey, interventions were selected based on their potential to reduce hazard from infectious disease. We focused on NBS that can reduce stagnant water, for example that collects after heavy monsoon rains on impervious surfaces and potholes in the road, as well as those that could reduce dependence on surface water and improve urban cooling.

Green streets

Street greening could combine paved walkways for pedestrians lined by trees and "bioswales" – gently sloped vegetated channels designed for infiltration of stormwater runoff. They can also support with treatment of combined sewer overflow through biofiltration. Street trees would further enable natural infiltration of water while improving urban temperatures (see Figure 5).

However, such retrofits are costly. Interventions may need to be undertaken alongside planned road upgrading to be financially feasible. Additionally, construction design codes – for instance that specify the width of the road, distance between dwellings and the road, footpaths and sewerage – may need to be updated to include NBS. Regular maintenance of the vegetation would be required to ensure that drains remain unclogged and fallen leaves are swept away to maintain cleanliness and functionality, which ensures no stagnant water in which mosquitos or other disease-carrying species might breed.

During the workshop, local actors highlighted that urban greening is already a city-wide priority, under the policy “Green Bharatpur, Clean Bharatpur”, which has included urban tree-planting beside footpaths. However, bioswales are not currently being implemented, which represents an opportunity for adding further multifunctionality. As an alternative to bioswales, percolation pits or “soak pits”, which utilize layers of natural material such as rocks, gravel and sand to filter and store rainwater underground, could be constructed as a simple and low-cost interventions at known flooding sites.

Figure 5. Left – Main highway in Bharatpur, which could be a potential site for NBS intervention. Right – rendering of green street design proposed for Udon Thani in Thailand.

Rainwater harvesting

Collecting rainwater on rooftops and filtering it using simple technology to provide a household water supply could solve several issues at once. Rainwater harvesting would be particularly useful in Ward 29 as a stopgap to improve hygiene and minimize outbreaks of skin infections until adequate piped water can be supplied. Local actors agreed that rainwater harvesting could be implemented in schools, public buildings and at household scale. Municipal actors might introduce some funding support for underserved households to construct rainwater harvesting interventions. Potential risks include damaged lids or walls of the percolation pits of harvesting tanks, resulting in water stagnation as habitat for mosquitos (Mariappan et al., 2008).

5. Conclusion

In rapidly growing secondary cities in Asia such as Bharatpur, steps should be taken to keep urban populations healthy – particularly given the complex ways diseases might evolve under climate change. Tackling infectious disease and its intersection with urban infrastructure, services and climate change will require enhanced collaboration between Departments of Health, Disaster Risk Reduction, urban planners, local government and civil society actors to identify health hazards and co-develop solutions.

We found associations of dengue fever and skin infections to proximity to garbage disposal sites, and a further association of skin infections to reliance on surface water as a domestic water source. These findings underscore the critical importance of basic urban infrastructure and service provision for reducing hazard – particularly municipal solid waste management and household piped water coverage. Emphasis should also be placed on addressing service delivery and infrastructure gaps to critically underserved peri-urban communities.

We explored the possibility with representatives of target communities of adopting NBS such as green streets and rainwater collection – solutions that elicited positive responses, even if only as stopgap measures. These and other NBS could support reduced hazard, for instance, through improving urban temperatures and encouraging natural infiltration of floodwater. However, NBS can only be effective if adequate urban infrastructure, for instance infrastructure that supports the provision of water and effective disposal and treatment of waste, is already in place. Moreover, we emphasize that the relationship between blue-green space and diseases such as dengue is complex, and effective design and maintenance is critical to mitigate risks.

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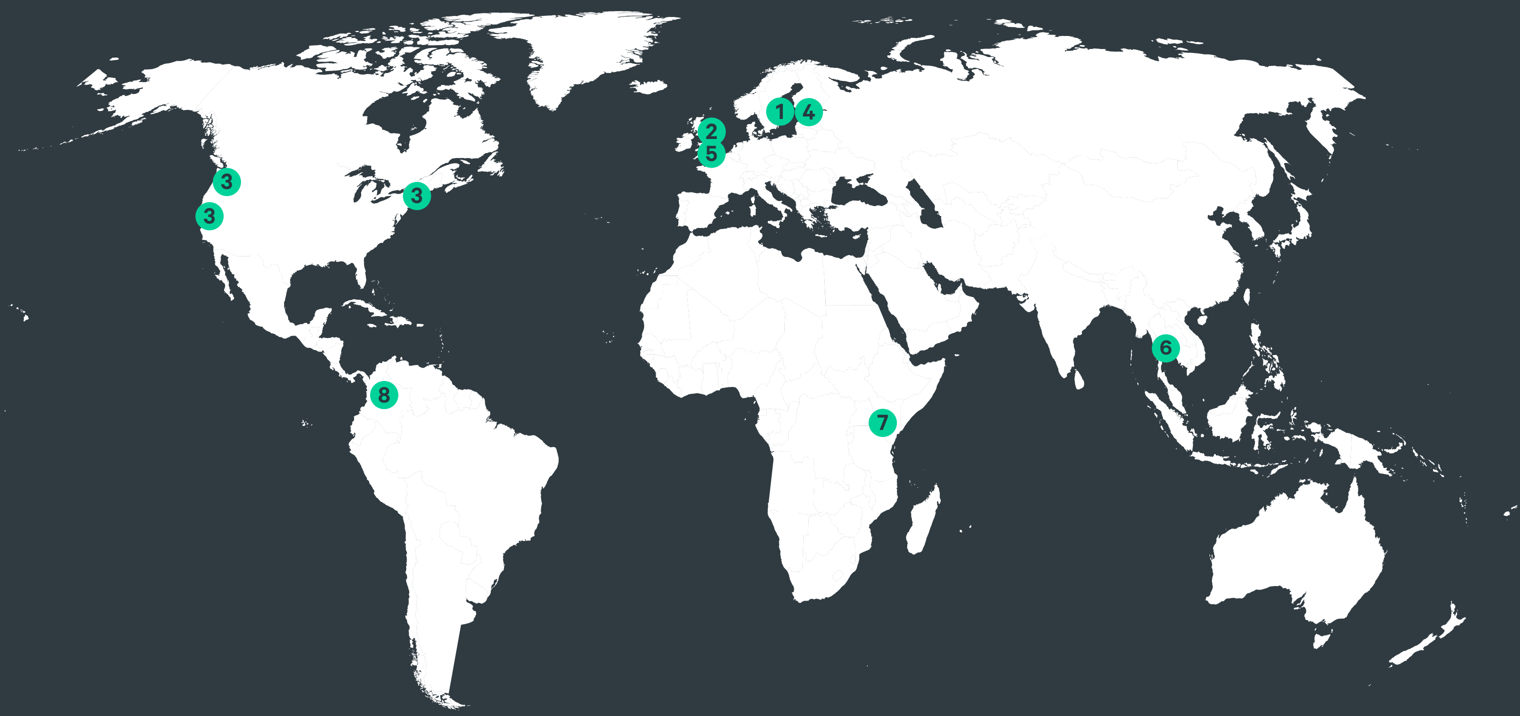

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