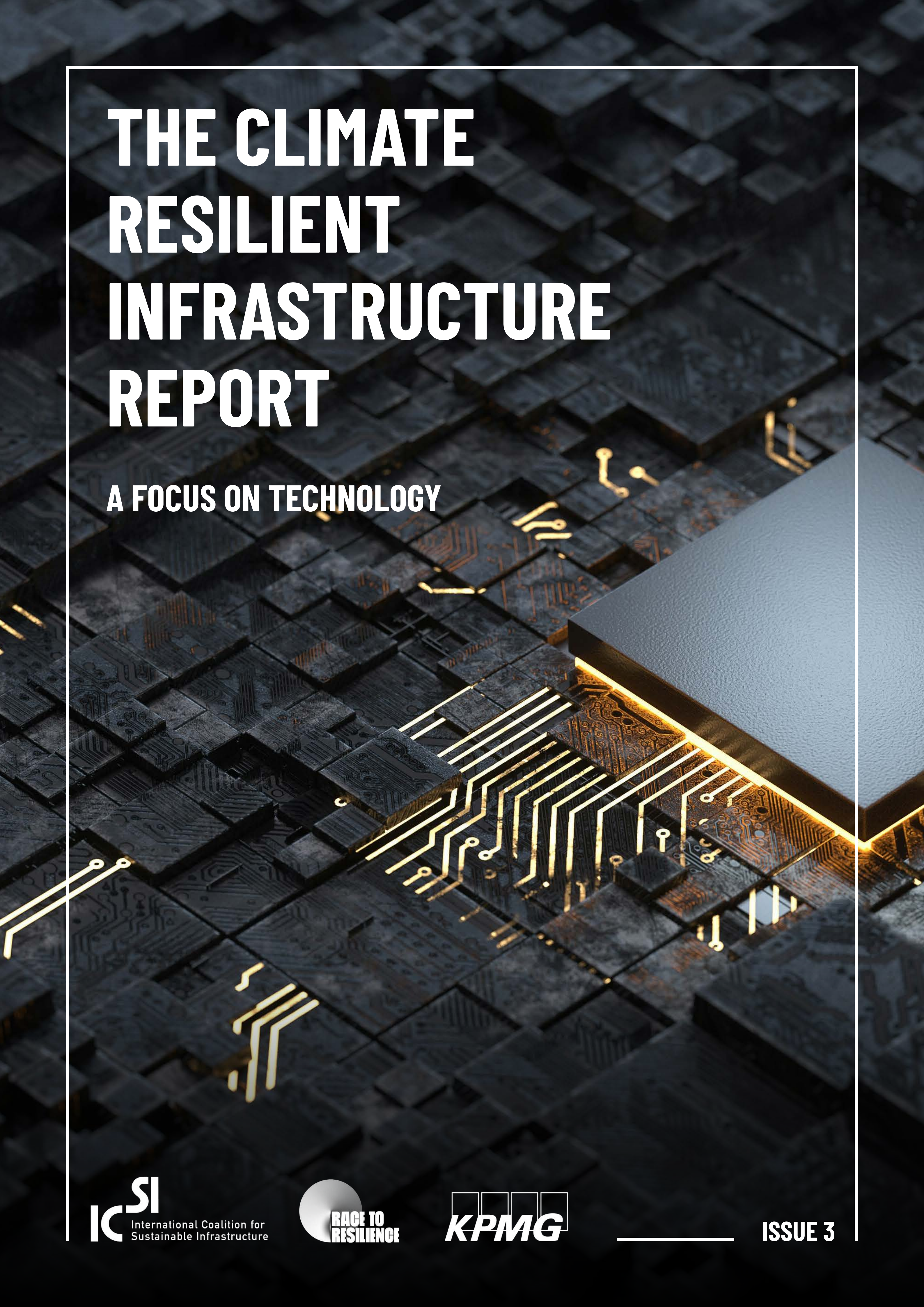

THE CLIMATE RESILIENT INFRASTRUCTURE REPORT

A FOCUS ON TECHNOLOGY

ICSI International Coalition for Sustainable Infrastructure

RACE TO RESILIENCE

KPMG

ISSUE 3

ABOUT ICSI

The International Coalition for Sustainable Infrastructure (ICSI) was founded in 2019 by Resilience Rising, the American Society of Civil Engineers (ASCE) and its ASCE Foundation, the Institution of Civil Engineers (ICE), the Global Covenant of Mayors for Climate & Energy (GCoM), WSP and LA Metro, among others. We bring together a global coalition of change agents from across the engineering, investment, city, and philanthropic communities committed to bold action to solve the systemic problems that exist at the intersection of climate change, ecosystem degradation, ageing infrastructure, and underinvestment. ICSI is the global movement for engineering action on infrastructure sustainability, resilience, and climate change. We place engineers at the forefront of climate action, harnessing their ability to provide solutions and matching it with urgent demand. The solutions we develop and promote will deliver impact on the ground, where it is needed most. ICSI was created to bring the practical, science-based, and solution-oriented perspective for which engineers are known to solve the systems-level problems surrounding infrastructure underinvestment, climate change, and resilience.

From its origin, ICSI has been committed to driving action towards instilling sustainability and resilience as the cornerstone of every decision in the infrastructure lifecycle. Built upon a commitment to tangible and collaborative action, ICSI continues to broaden participation across other stakeholder communities to accelerate the innovation, adoption and scaling of people-centred, sustainable, and resilient infrastructure solutions that support sustainable development for all.

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Global initiatives:

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41 42 43 46 50 51 52 53

CLIMATE RESILIENT INFRASTRUCTURE: A FOCUS ON TECHNOLOGY CASE STUDY INDEX

CREDITS

Editing

Savina Carluccio

Gemma Cowan

Research

Jasmine Andean

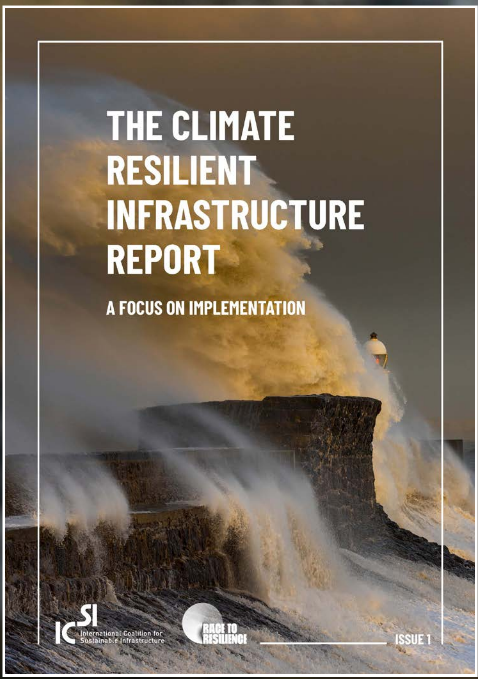
Arabella Liu

Robert Parlett

Design

Roman Svidran

PREVIOUS ISSUES



The Climate Resilient Infrastructure Report: A Focus on Implementation

The Climate Resilient Infrastructure Report: A Focus on Nature

A Word from the COP29 High-Level Climate Champion

The International Coalition for Sustainable Infrastructure (ICSI), a valued partner of the Race to Resilience campaign, delves into the emerging technologies that are reshaping the future of infrastructure. The report highlights best-practices and case studies of technology applications that foster both resilience and innovation across all infrastructure sectors. Central to this necessary transformation is the unique role of SMEs, which act as a driving force behind innovation, technological advancement, job creation, and climate leadership. These enterprises are developing and deploying solutions that unlock unprecedented opportunities for climate-resilient infrastructure, ensuring that our systems are equipped and capable of adapting to the challenges posed by a changing climate.

Nigar Arpadarai

UN Climate Change High Level Champion for COP29, Azerbaijan

A Word from the sponsor

Climate change is a global phenomenon, with the impacts of increased natural disasters and severe weather events manifesting locally, affecting organisations, individuals and communities in profound ways. In a world flooded with data, there is an opportunity to harness the power of information to accelerate adaptation to such events and build more resilient infrastructure globally. When combined with emerging digital technologies, data-driven intelligence enables speed-to-action, cultivating more proactive preparation, response, and recovery at the local and asset level. This report examines the data and technology capabilities required to inform decision-making across industry and sector domains, with a focus on the critical role SMEs play in building more resilient infrastructure. KPMG is proud to partner with The International Coalition for Sustainable Infrastructure (ICSI) to explore how data and technology solutions can untangle a complex web of climate uncertainty, ensuring greater confidence in the actions we make today, to build a more resilient future tomorrow.

Kristofer Canto

KPMG-US, Sustainability

Foreword

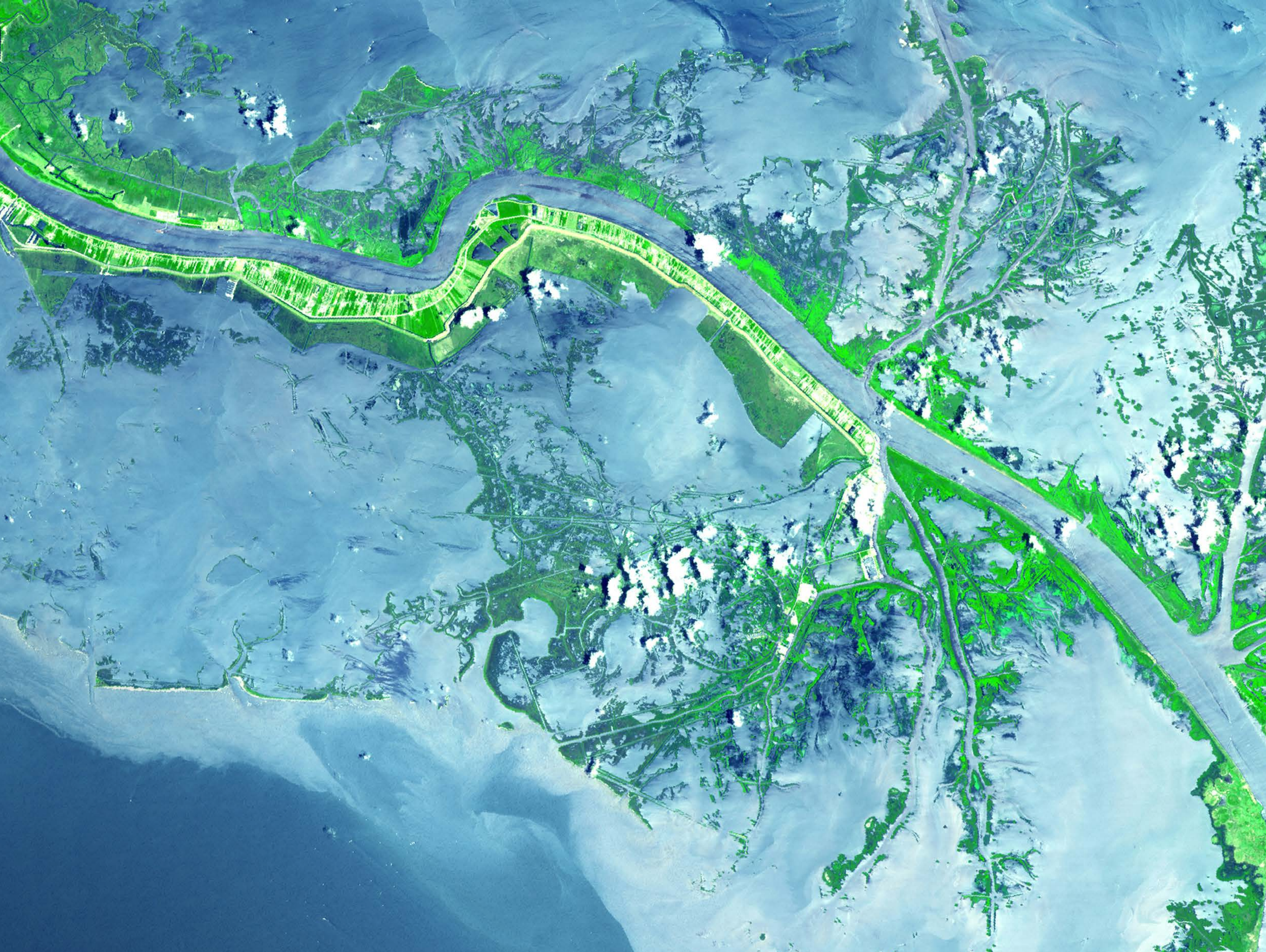
Climate adaptation requires flexible design and planning with a razor-sharp focus on reducing the fragility of infrastructures. Protective infrastructure systems such as dams and levees have traditionally been designed to withstand failures, while lifeline infrastructure systems such as transportation networks and power grids have traditionally been designed for operational efficiency. Climate resilience, however, demands safe-to-fail design with grey-green protective infrastructures and embedded resilience principles into the design, retrofitting, maintenance, operations, and recovery of highly interconnected infrastructure and human networks.

Research, practice, and policy communities must explore the possibilities of using traditional and emerging technologies and data-driven sciences to address the complex, intersecting, and cascading challenges that climate change poses. Technologies include performance-based engineering, as well as grey-green, safe-to-fail, and nature-based design. Examples range from flexible design principles that allow adaptive hardening of infrastructure to giving rivers room to breathe and preserving mangroves along coastlines. Data-driven sciences include network sciences and optimisation, artificial intelligence (AI) methods from computer vision, generative AI, small and large language models, and small- or large-sample foundation models, along with physics-integrated and human-reinforced learning. Examples range from the design of hydraulic networks, frugal innovations of flood-resilient houses on stilts, and AI systems that can emulate large weather and climate models.

There is early evidence across a range of related disciplines that intelligent blends of knowledge, including, scientific theories, techno-social principles, and data-driven simulations, when combined with state-of-the-art and new data-driven sciences including AI, can lead to dramatic breakthroughs. An example of this can be seen in cyclone resilience. Cyclone predictions are improving in European centre weather models, which in turn use AI. Low-cost shelters have saved lives during cyclones in India, and social media and human networks have helped in rescue and recovery after cyclones.

The ability to bridge the research, practice, and policy divide would require innovative startups and community engagements, as well as an experientially trained workforce. This report showcases projects and initiatives that are leading the way in harnessing emerging technologies for climate-resilient infrastructure. Practitioners, policymakers and academics alike should be motivated to learn from these innovative applications of technology and incorporate these learnings into their own practice.

Professor Auroop R. Ganguly
Northeastern University, Boston, MA, USA



Contents

1. INTRODUCTION

The Climate Resilient Infrastructure Report series was first launched in May 2023 in an effort to report progress on the state of climate-resilient infrastructure and showcase best-practice case studies and initiatives from around the world. The series contributes directly to the UNFCCC Race to Resilience campaign, which seeks to catalyse action by nonstate actors to build the resilience of 4 billion people from vulnerable groups and communities to climate risks by 2030.

We are excited to share the third issue of the Climate Resilient Infrastructure report. Issue 1, launched in May 2023, had a focus on implementation and featured case studies from across the globe. Issue 2 was launched at COP28 and took a closer look at the relationship between infrastructure and nature. You can read more about the series here.

Issue 3, A Focus on Technology, showcases platforms, tools and emerging digital technologies that advance climate-resilient infrastructure, as well as projects and initiatives that have incorporated them. The report explores how digital technologies can enhance decision-making for climate resilience and adaptation. For example, by modelling physical climate risks and impacts, providing an assessment of the condition of existing infrastructure, or supporting efficient and reliable decision-making, before, during and after hazard events.

The report is framed by the resilience phases: Prepare, Respond, Recover, and Adapt. With over 50 contributions, it highlights case studies that elevate the agenda for resilience and adaptation across all infrastructure sectors and showcase best-practice examples of technology applications that build and/or enhance resilience and sustainability. It features platforms, approaches, resources and capacity-building initiatives that can empower practitioners and local communities to embrace and harness technology to advance climate-resilient infrastructure. We shine a light on collaborations that champion diversity in problem-solving, leading to holistic, transferable and people-centred solutions, in addition to spotlighting a number of SMEs that are leading the way in developing tech solutions for climate action. Through this myriad of contributions, the work highlighted in this report has contributed to building and/or enhancing the resilience of over 119 million people worldwide.

The work highlighted in this report has contributed to building and/or enhancing the resilience of over 119 million people worldwide.

2. SPOTLIGHT ON TECHNOLOGY

This report looks at technology for infrastructure resilience through the lens of four distinct phases of resilience: Prepare, Respond, Recover, and Adapt. At each phase, digital technology has proven crucial to advancing innovations that increase infrastructure robustness, adaptability, and safety in the face of climate challenges.

PREPARE

In the preparation phase, digital technology helps in early assessment and monitoring, capturing real-time data on the status and performance of infrastructure assets. This data-driven approach allows infrastructure operators to predict and address potential vulnerabilities arising from age, environmental exposure, or climate-related stressors like extreme weather. Digital twins — virtual models of physical infrastructure — integrate data from various sensors and historical information, enabling predictive analysis. For example, AI algorithms assess asset wear, predicting failures before they occur and allowing proactive maintenance. By identifying risks early, digital tools reduce unplanned disruptions and ensure infrastructure readiness for climate-related challenges.

RESPOND

During hazard events, the response phase demands rapid, accurate information to guide interventions. Digital technologies such as remote sensing, drones, and crowdsourced data from smartphones offer real-time insights into an asset's condition and environmental impact. For instance, during floods or earthquakes, drones equipped with cameras and sensors can quickly survey affected areas, providing immediate, detailed images to responders. Additionally, data from social media and Internet of Things (IoT) devices help track conditions and notify authorities about specific incidents, aiding in decisions like evacuation routes or resource deployment. Systems bolstered by 5G networks allow faster communication and transfer of data, further enabling agile responses during climate-related crises.

RECOVER

The recovery phase focuses on restoring infrastructure functionality after disruptions. Digital technologies streamline this process by enabling remote inspections, real-time monitoring, and precise damage assessments. After an event, unmanned aerial vehicles (UAVs) can capture high-resolution images to map affected areas in 3D, providing data for rapid condition assessments. Autonomous inspection systems enhance recovery by reducing human involvement in dangerous situations, leading to safer, faster recovery efforts. These technologies offer accurate, reliable data for timely repairs and more resilient rebuilding.

ADAPT

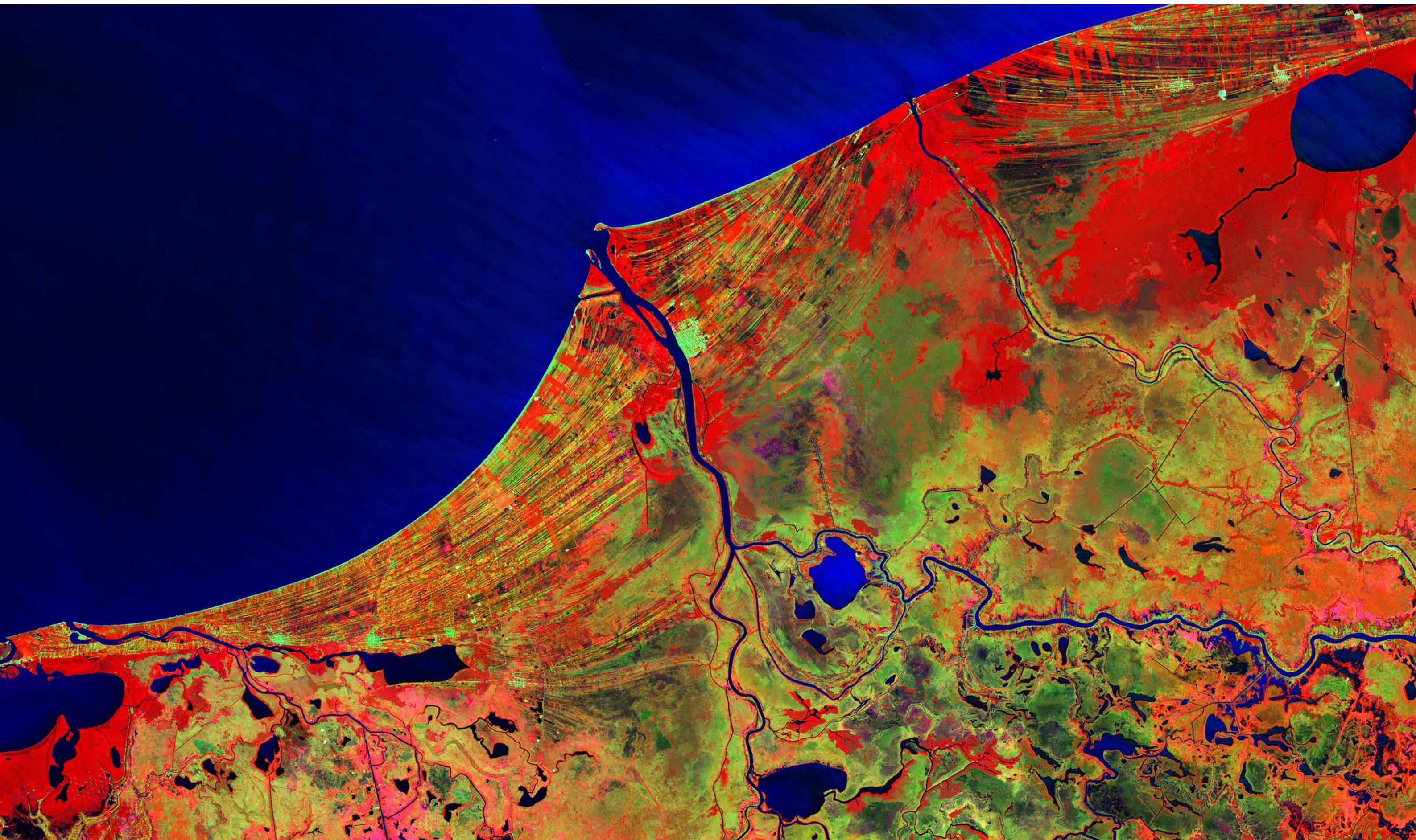
Adaptation involves making infrastructure resilient to future conditions by anticipating and addressing the impacts of climate change over the long term. In this stage, digital technologies support modelling and scenario planning to assess future risks and optimise infrastructure accordingly. For example, AI and machine learning can analyse climate projections, anticipate stressors, and suggest design improvements that minimise resource use while maximising resilience. Agent-based modelling (ABM) evaluates infrastructure network interdependencies, identifying critical areas for reinforcement or redesign. Additionally, self-aware assets equipped with embedded sensors provide continuous updates, helping operators track performance and adjust strategies to suit changing conditions. Over time, this proactive monitoring and adaptation minimises maintenance costs and reduces environmental impacts, contributing to infrastructure longevity.

The role of digital technology in furthering global climate agendas

Digital technology's role in infrastructure resilience is transformative. By providing tools for early detection, immediate response, efficient recovery, and long-term adaptation, these technologies foster infrastructure systems that are safer, more sustainable, and better equipped to withstand climate change. They also directly support global climate agendas, including the Sustainable Development Goals (SDGs). For example, SDG 9 (Industry, Innovation, and Infrastructure) emphasises resilient infrastructure as a foundation for sustainable development, while SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action) focus on adapting cities to climate risks.

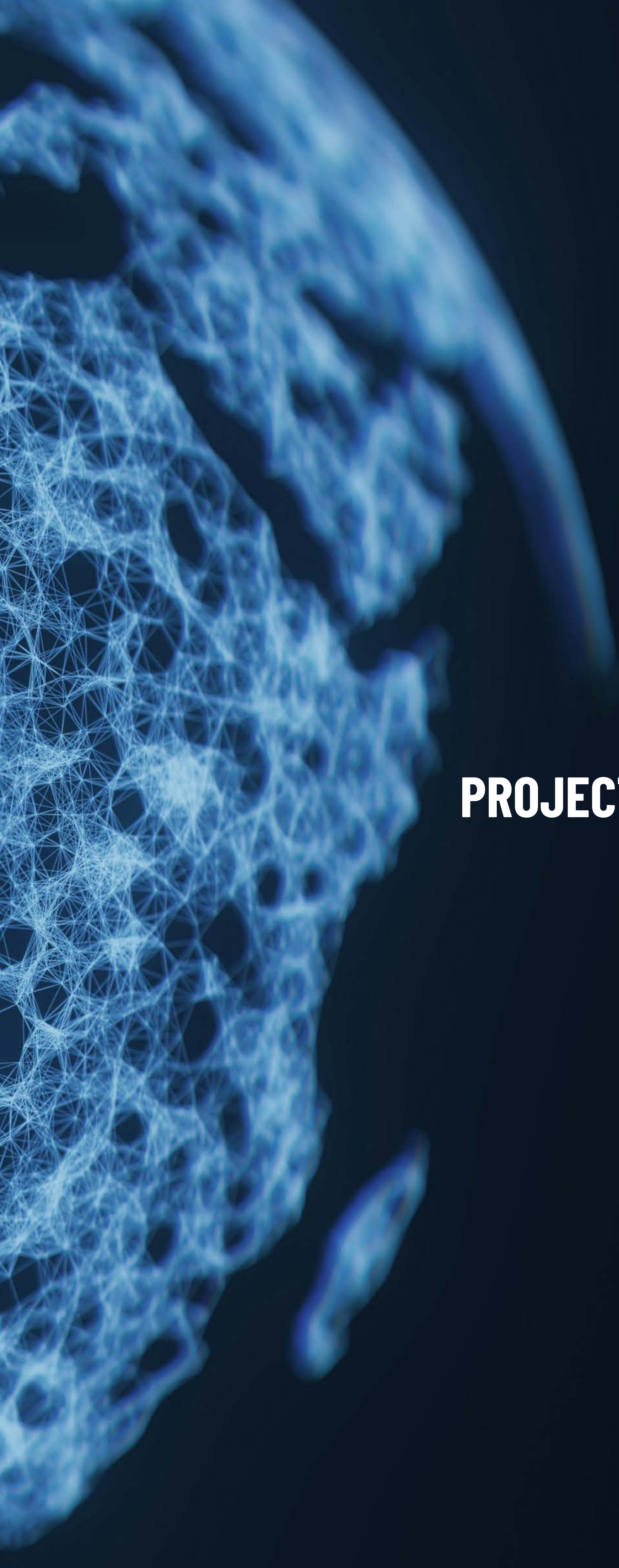
The role of emerging digital technologies in enhancing climate-resilient infrastructure is also directly aligned with the Sharm el-Sheikh Adaptation Agenda (SAA). For example, the SAA calls for universal access to data and analytics to better integrate climate risks and impacts into decision-making. Additionally, the adaptation outcome for transport infrastructure explicitly mentions the adoption of new technologies to make infrastructure more resilient to climate hazards. The private sector, and SMEs in particular, will play a critical role in advancing these technologies and making them accessible for climate action.

Through each resilience phase, digital technologies fulfil key global climate objectives, fostering resilience, mitigating climate risks, and supporting sustainable development. This alignment not only strengthens infrastructure but ensures communities can adapt to climate challenges with agility, creating a foundation for resilient, inclusive development in line with global adaptation goals.



2.1 PROJECTS AND SOLUTIONS

The projects and solutions showcased here serve as best practice examples from across the globe. From early warning systems in flood-prone communities to disaster response and humanitarian efforts, these case studies each demonstrate ways that technology has been harnessed to deliver infrastructure solutions that prioritise human wellbeing and build climate resilience and adaptation. The case studies all help to build progress towards the Sharm El-Sheikh Adaptation Agenda outcomes and contributions to the Race to Resilience target have been highlighted where relevant.



PROJECTS

ADAPTIVE PLANNING FOR UK GREEN RECOVERY PROGRAMME

Sector

Water

Resilience Phase

PREPARE RESPOND RECOVER **ADAPT**

Highlights

Biodiversity | Carbon mitigation | Community wellbeing | Ecological uplift

Project owner
Severn Trent Water

Project start/completion
March 2021 – December 2030

Location
United Kingdom

Communities impacted
Rural, Urban

Hazards mitigated
Water stress, Drought

Case study provided by:

ARCADIS

Number of people made more resilient

~ 8 Million

LEARN MORE

RACE TO RESILIENCE

Severn Trent Water (STW) faced the challenge of ensuring water supply resilience and achieving carbon neutrality amidst climate and economic uncertainty. Partnering with Arcadis, they utilised Decision Making under Uncertainty and Adaptive Planning Optimiser tools to develop robust investment plans. This approach secured a £565 million investment for STW's Green Recovery programme, promoting sustainable water management and green economic recovery in the UK.

ABOUT THE PROJECT

In mid-2020, regulators in the English water industry challenged water utilities to 'build back greener' from the COVID-19 pandemic, delivering lasting environmental improvements for current and future generations, while addressing economic and social challenges. This came after a dry spring, an unprecedented rise in water consumption as a consequence of lifestyle changes due to lockdowns, and the increasingly severe effects of climate change.

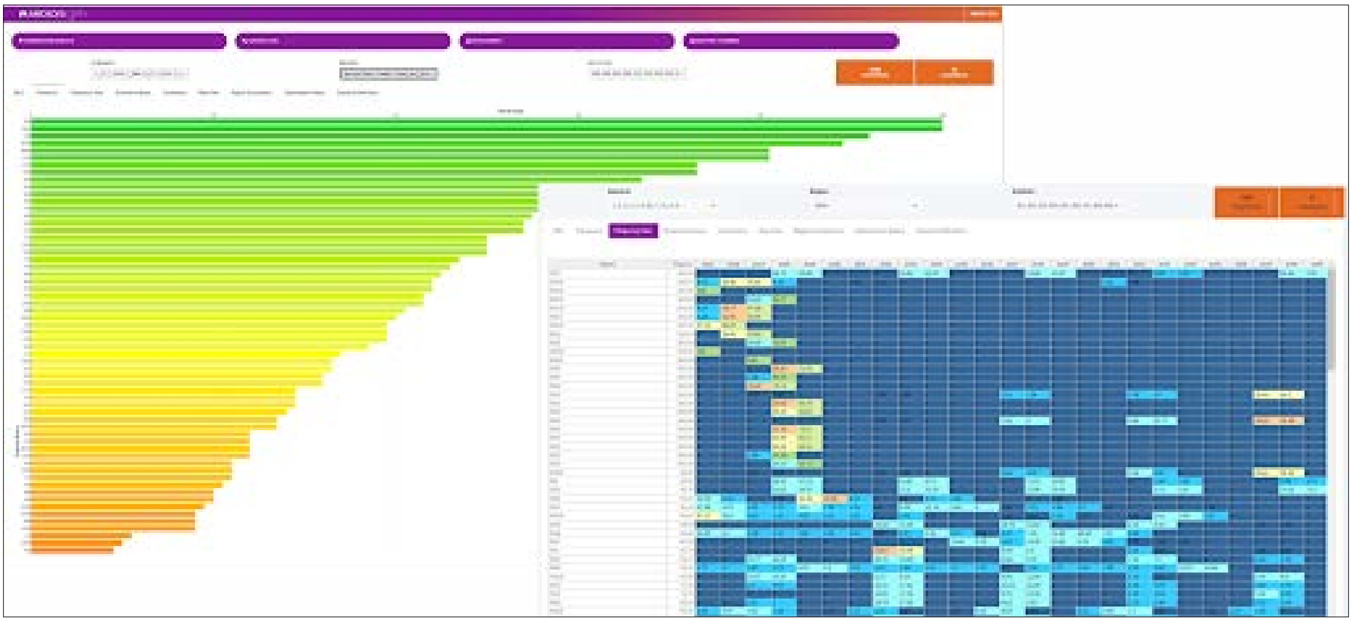
STW faced the critical challenge of addressing the environmental and social impacts of water supply, severe 1 in 500-year drought scenarios, heightened water consumption and escalating climate effects. They needed an innovative approach to develop an investment plan that met multifaceted demands while balancing financial, environmental and social priorities.

STW partnered with Arcadis to utilise the Decision Making under Uncertainty (DMU) and Adaptive Planning Optimiser (APO) digital tools, that form part of Arcadis's technology and solution stack, The Enterprise Decision Analytics (EDA) platform. The DMU tool processed extensive 25-year projections of supply and demand data for the Water Resource Zone, along with numerous solution options and their associated uncertainties.

This generated thousands of optimised investment simulations, with the goal of creating robust investment plans based on 'least regret' options across multiple climate scenarios (see Figure 1 for example outputs). By identifying which projects are always selected regardless of the climate future, increased confidence is provided that the best decisions for the region and community will be made.

Figure 2 presents the user interface used to set up Adaptive Pathway Optimisation models, which allows for dynamic, optimised adjustments to the 25-year investment strategy. This ensured STW interactively engaged with the data and could pivot their plan as new climate data emerged, optimising water demand management and environmental goals.

No and Least Regrets Decision Analyses, Represented as Frequency Graphs.



Adaptive Pathway Selection User Interface for Scenario Generation

The technology used had never been applied outside of academia before and it resulted in such a robust plan that STW was able to secure a £565 million investment from The Water Services Regulation Authority (Ofwat), from a total of £793 million available to the entire water industry in England. STW will implement six major schemes ensuring sustainable water management for the future:

#	NAME	DESCRIPTION	INDICATIVE BUDGET (£M)	DISTRIBUTION (%)
1	**Accelerating environmental improvements**	Improve river quality by upgrading sewage treatment works, treating and reducing spills from storm overflows, and installing river quality monitoring	169	30%
2	**Building sustainable flood-resilient communities**	Protect homes from flooding through nature-based solutions	76	14%
3	**Creating bathing rivers**	Trial the creation of two bathing rivers, including reducing harm from storm overflows by reducing spills into the area during the bathing season	78	14%
4	**Decarbonising water resources**	Increase water supplies in a low carbon, reduced chemical way, through a combination of supply-side and demand-side solutions	140	25%
5	**Smart metering**	Help customers save water by installing smart water meters	20	4%
6	**Taking care of supply pipes**	Replace and repair customer supply pipes, reducing health risks from lead pipes in two trial areas	75	13%
		TOTAL	**558**	**100%**

ACHIEVED OUTCOMES

Social

This project has significantly improved the equitable provision of safe drinking water to customers and reinforced their security against future climate change scenarios. Supply-side resilience has reassured customers that they are protected from future demand and climate changes and communities will benefit from having more resilient urban and rural spaces. Additionally, social equity has been considered in the project to ensure that appropriate access to resources is provided for underprivileged and at-risk communities.

Nature-based solutions (NbS) have been integrated with sewage infrastructure upgrades, river quality monitoring and reducing spills from storm overflows and as such have supported the construction of sustainable, flood-resilient communities. Not only are these communities protected from flooding and overflow events, but many have gained access to STW's bathing rivers that are being trialled in sections of the River Teme and the River Leam. This is done in partnership with local farmers, authorities and other stakeholders as part of their 'Get River Positive Campaign' under the Green Recovery Programme.

Environmental

The road to carbon neutrality has been a priority of STW and as such they have continuously invested in minimising the future impacts of carbon-heavy processes. Decarbonising water resources and removing toxic chemicals and contaminants from water streams were integrated into two of STW's six investment plans. Furthermore, STW has supported the growing resilience of natural systems by enhancing natural biodiversity both in and around water sources, through the valuation of additional multi-criteria benefit analyses for all considered investment options, as well as including value maximisation through the scenario analysis objectives – thus ensuring that promoted schemes are not just selected on the basis of least cost. This has resulted in investments being endorsed by the board and regulator, supporting the restoration of natural capital.

Additionally, the bathing rivers will create the right conditions for aquatic wildlife to thrive while delivering enhanced water quality over a 50km span. This will fast-track investments in stormwater management, pollution reduction and catchment management strategies, as outlined in the plan.

Economic

STW are maximising returns for shareholders while ensuring their 8 million customers are not only getting value for money but are more secure against future climate change scenarios. Their 25-year investment plan is optimised to maximise community value, enable adaptation to future climate uncertainties and support financial sustainability.

BLOCKCHAIN TECHNOLOGY FOR CLIMATE-RELATED HUMANITARIAN CRISES

Sector

Telecommunications

Finance

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Biodiversity | Safety | Disaster Management | Humanitarian Relief | Healthcare

Project owner
UN World Food Programme

Project start/completion
Pilot in Pakistan in 2017 – ongoing

Location
Zaatari Refugee Camp, Jordan

Communities impacted
Urban

Hazards mitigated
Drought, flooding, Extreme weather

Case study provided by:
UN World Food Programme

Number of people made more resilient

106,000
in Zaatari refugee camp

4 Million
people per month globally

LEARN MORE

The World Food Programme's Building Blocks initiative serves as a prominent example of how blockchain technology can enhance aid efforts in climate-vulnerable regions such as the Zaatari refugee camp in Jordan.

ABOUT THE PROJECT

Blockchain technology has emerged as a transformative tool in the management of disaster relief efforts, particularly in response to climate-induced crises like floods, droughts, hurricanes, and wildfires. By leveraging blockchain's features of transparency, immutability, and decentralised control, humanitarian organisations can respond more efficiently, reducing fraud, delays, and inefficiencies often present in traditional aid distribution systems.

The Building Blocks initiative, developed by the UN World Food Programme (WFP), is the world's largest blockchain-based system for humanitarian aid distribution. It utilises blockchain technology to improve the efficiency and transparency of aid delivery, particularly in contexts affected by climate change. By integrating blockchain, the system enables multiple humanitarian organisations to coordinate their efforts, reducing overlaps and ensuring that aid reaches those in need more effectively.

Initially piloted in Pakistan, Building Blocks has since expanded to serve millions of refugees and effected populations in Bangladesh, Jordan, Lebanon, and Ukraine. The project leverages blockchain to manage cash-based transfers, providing vital assistance such as food, water, and sanitation resources. In Jordan's Zaatari refugee camp, home to thousands of Syrian refugees who have been displaced due to climate-related drought and conflict, Building Blocks has played a crucial role through the use of smart contracts that facilitate faster aid distribution. This capability is particularly crucial in the context of climate-induced disasters, where immediate action is essential to minimise damage and loss of life.

Blockchain technology forms the backbone of Building Blocks, enabling the system to operate in a decentralised and transparent manner. Its decentralised nature ensures that no single organisation has complete control, fostering collaboration between multiple humanitarian agencies. This collaborative approach enhances resilience by pooling resources and expertise, allowing organisations to respond more effectively to crises.

Additionally, blockchain's immutable ledger system records every transaction, preventing fraud and ensuring accountability. This feature builds trust among stakeholders — governments, NGOs, and donors — enabling them to trace funds and resources and ensuring that assistance is delivered accurately and promptly. By guaranteeing that aid reaches its intended recipients, the technology enhances the resilience of vulnerable communities and ensures consistent and reliable support during climate crises.

ACHIEVED OUTCOMES

Social

The implementation of Building Blocks in the Zaatari refugee camp has improved the social well-being of refugees by streamlining access to essential resources. With blockchain, the distribution of aid such as food and water is more efficient, and recipients can access multiple forms of support through a single platform. This reduces the need for refugees to engage with multiple aid agencies, simplifying their experience and reducing stress.

Additionally, blockchain's transparency builds trust between aid providers and recipients. Refugees can be confident that the aid they receive is legitimate and allocated fairly. The WFP has also collaborated with other organisations, such as UN Women, to integrate cash-for-work programmes, providing income opportunities for refugees. This has empowered individuals within the camp, fostering a sense of agency and community resilience.

Economic

Economically, the Building Blocks platform has demonstrated significant cost savings in aid distribution. By eliminating intermediaries and streamlining transactions, the WFP has reduced banking fees by over $3.5 million in its operations in Jordan. These savings allow organisations to reinvest funds directly into supporting additional beneficiaries and expanding their reach.

In the Zaatari refugee camp, refugees benefit economically by having access to cash-based assistance. This allows them to purchase goods directly, supporting local markets and small businesses. The increased efficiency in aid delivery also means that economic resources are allocated more effectively, reducing waste and ensuring that funds reach those who need them most.

BUILDING FLOOD RESILIENCE OF SCHOOLS IN THE DOMINICAN REPUBLIC

Sector

Construction

Education

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Community engagement | Inclusivity | Community wellbeing | Education | Safety | Disaster management | Mobility | Humanitarian Relief

Project owners
UNESCO Chair in Disaster Risk Reduction and Resilience Engineering, University College London

Project start/completion
Feb 2023 – Dec 2023

Location
The Dominican Republic

Communities impacted
Urban, Rural

Hazards mitigated
Flooding

Case study provided by:

UCL

unesco Chair on Disaster Risk Reduction and Resilience Engineering

Number of people made more resilient

56,000

LEARN MORE

RACE TO RESILIENCE

UNESCO Chair in Disaster Risk Reduction and Resilience Engineering (DRR&RE) at University College London (UCL) have combined multiple simulation and modelling tools like Bayesian Network, Monte Carlo simulation, and Agent-based modelling (ABM) to assess and enhance the resilience of schools against floods in the Dominican Republic.

ABOUT THE PROJECT

Public education is considered a fundamental service that governments should offer to their population. However, this service is prone to disruptions caused by natural hazards like floods. Besides physical damage to school buildings, factors such as the inability to commute (due to blocked roads, for example), also affect the capacity to restart classes.

To evaluate the risk of education disruption caused by floods, the UNESCO Chair DRR&RE at UCL, have developed a methodology that considers both the physical school infrastructure in a region and the road network that serves it. The proposed method integrates multiple simulation and modelling tools like Bayesian Network, Monte Carlo simulation, and Agent-based modelling.

Using a Bayesian Network, it is possible to calculate the probabilities of different states of damage under chosen return periods and intensity of rainfall causing flooding. The Monte Carlo simulation is then adopted to evaluate all possibilities of operational states of each school in a region. The ABM accounts for two agents, namely 'School Operator' and 'Road Operator', who work interactively and are responsible for the recovery activities of school buildings and roads respectively. This integrated approach enables explorations of many different scenarios and enables policymakers to compare different recovery and retrofitting strategies to support the proposal of informed resilience enhancement policies. In turn, this contributes to more informed decision-making for building resilience.

To demonstrate the feasibility and effectiveness of the proposed approach, this methodology was implemented in the province of San Pedro de Macoris, the Dominican Republic, considering a flood with a return period of 50 years. The two main local partners in the implementation of this project were the Ministry of Education and ONESVIE, the institute in charge of reducing the vulnerability of existing buildings and infrastructure in the country.

Results show that the minimum, median, and maximum recovery times of education services are 58 days, 75 days, and 100 days respectively, after being interrupted by the flood. When applying more efficient recovery strategies, like a greedy algorithm (which makes locally optimal choices to find a globally optimal solution), the resilience level can be improved significantly, from the original 0.328 to 0.617 at most. This indicates that the recovery will progress at a more rapid rate, especially in the early stages, returning more children to schools. A dry flood-proofed mitigation strategy was proposed for each school building located in the susceptible area, which further improves the resilience level to 0.690, meaning that a lesser number of children will be affected, and the total recovery time will be shortened. In addition, a simple and relatable cost metric, the cost of reducing one day of interruption per student, was proposed to provide meaningful insights for non-technical audiences and decision-makers. Results show that the proposed mitigation strategy is able to reduce the total recovery time by 39 days for the whole province while costing around $26 per reduced day per student directly benefiting from the intervention.

Community engagement is an important aspect of the project. The UNESCO Chair DRR&RE team visited four schools during implementation to discuss the negative impacts of natural hazards on education. During the discussions, the impacts of floods were discussed, including how these events isolated schools and communities during the flooding period. Additional needs in the schools were discussed such as the relevance of improving Water and Sanitation Hygiene (WASH) and energy efficiency in parallel with the structural retrofitting. In addition, the project team participated in a workshop in Santo Domingo that included several national and international stakeholders interested in improving school infrastructure. Two main takeaways were obtained from these discussions: 1) as the nation is improving its digital infrastructure to provide more transparency on policies, there is a need for a centralise and integrated information system for school infrastructure that could be updated in real-time, and 2) the expansion of the project to the other provinces and to the national level should be a priority in order to improve preparedness at local and national level, by promoting evidence based decision making and budget allocations .

INTENDED OUTCOMES

Social Outcomes

With the proposed approach, the education disruption caused by floods in San Pedro de Macoris can be significantly minimised. The improved resilience will allow the local students to resume education in a timelier manner after major events, but also to avoid any disruption in the case of flash flooding and minor events.

The results from this project can be used to implement disaster risk mitigation strategies that can benefit around 56,000 students located in the province of San Pedro de Macoris. The implementation of these measures will potentially benefit the extended community of all inhabitants in the province considering the improvement in the response and recovery strategies as well as the use of schools as shelters. In addition, this transferable and scalable approach will potentially benefit around 1.5 million students in public schools across the country when it is promoted nationwide.

Environmental Outcomes

The outcomes of this project can be used to inform disaster risk mitigation by improving existing school buildings. This has an important environmental impact since we are proposing to adapt already built infrastructure to climate events rather than replacing it (which would have a worse environmental impact). While the specific gain in reduced emission and more sustainable use of resources is difficult to quantify accurately without a more detailed study of the construction processes employed in the region and the future school typologies programmed, the World Economic Forum estimates that retrofitting an existing building can result in 50 to 75% less carbon consumption than building it from scratch.

Economic Outcomes

The proposed approach contributes to capturing the vulnerabilities of the education service and proposing informed recovery and retrofitting strategies, which will reduce the costs caused by natural hazards. In addition, with the ability of scenario deduction of the modelling tools and the newly developed cost metric, decision-makers are also able to identify the most cost-efficient ways to enhance the resilience of school infrastructure. Loss of school days ultimately amount to loss of human capital for a nation, i.e. loss of acquired skills and knowledge that can improve the productivity and economic outlook of a country. Therefore improving the resilience of the infrastructure is not only beneficial in terms of mitigating direct economic losses and recovery costs, but also in terms of safeguarding and ensuring the sustainability of development policies, for low middle income countries.

EARLY WARNING SYSTEMS IN MALAWI

Sector

Telecommunications

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Community engagement · Inclusivity · Property protection · Collaboration · Safety · Disaster management

Project owner
United Nations Children's Fund (UNICEF Malawi)

Project start/completion
January 2021 – August 2024
(Royal HaskoningDHV Assignment)

Location
Northern Malawi

Communities impacted
Rural

Hazards mitigated
Flooding

Case study provided by:
MUBAS Malawi, Malawi Red Cross, 510 Red Cross The Netherlands

Royal HaskoningDHV Enhancing Society Together

unicef for every child

Number of people made more resilient

2.5 Million

LEARN MORE

RACE TO RESILIENCE

As part of its Climate Adaptation Program, UNICEF worked with Royal HaskoningDHV and The Red Cross to provide an early warning flood protection system for the people of Malawi.

ABOUT THE PROJECT

In 2020, UNICEF assigned Royal HaskoningDHV to help update an existing flood prediction system for the districts of North and South Rukuru which are prone to regular and extensive flash flooding, with large impacts on the communities and local economy.

The project involved a range of stakeholders, including the Malawian Department of Water Resources, the Department of Climate Change and Meteorological Services, the Department of Disaster Management, The Red Cross, and the University of Malawi. All of these stakeholders were working on behalf of the Department of Disaster Management and Water Resources and the Department of Climate Change and Meteorological Services.

Royal HaskoningDHV initially conducted an assessment of Malawi's existing systems, like the Operational Decision Support System implemented by the World Bank in the Lower Shire River region (Southern part). While carrying out this work, the need for a similar solution for the north of Malawi – an area often impacted by flash floods – became apparent, and Royal HaskoningDHV was tasked with overseeing the implementation of this project.

The project started with the development of flood models for the region, but the goal was to have a fully functioning community- and impact-based early warning system (EWS). Despite limited development options due to tight budgets, the involvement from the Red Cross meant that funding for their Early Action Protocols, along with funding from the Department for Water Application in the Netherlands, could support a solution based on the Red Cross's own forecasting system.

Drone footage showing extent of floods in Malawi, December 2022.

Royal HaskoningDHV therefore worked alongside the Red Cross to update this system – originally based on satellite modelling – with its own more advanced data models. This provided more accurate flood maps, insight into the likely impacts of flooding, and a greater level of accuracy for flash flood predictions. The result was the creation of an interoperable flood prediction system that provides near real-time flood risk data and insights informing the entire EWS in Malawi.

The advanced warnings will help the local government protect assets and save lives for the foreseeable future. The platform has been fully operational since mid-2024. Additionally, this project has shown the possibilities of collaboration between private sector and non-profit organisations to advance resilience to climate change.

OUTCOMES

Social Outcomes

Flood EWS in developing countries like Malawi provide significant social benefits. This particular EWS empowered communities in Karonga and Rumphi with timely information for flood risk preparation and response. This included setting up alerts based on triggering events that are expected to significantly impact the population in a certain area. In Northern Malawi, well-used WhatsApp groups between the different departments (Water Resources, Climate Change and Meteorological Services and Disaster Management) and communities effectively disseminate warnings through local representatives. The EWS has been proven to improve safety and reduce casualties by enabling timely evacuations and preventive measures, particularly benefiting vulnerable populations like refugees, impoverished groups, women, and the elderly. The system also fostered social cohesion by encouraging community cooperation and collective action in disaster preparedness. To boost this communication, a parallel track on community engagement around the EWS was executed by the local Red Cross and UNICEF partners, building the capacity of district councils and communities to use this EWS.

Environmental Outcomes

The EWS have positive environmental effects, although these may be less documented than social outcomes. They enable communities to protect vulnerable ecosystems and natural habitats from flood damage, helping maintain ecosystem integrity crucial for local livelihoods. EWS improve water resource management, including dams and reservoirs, supporting sustainable agricultural practices. This leads to reduced environmental degradation associated with crop losses. Additionally, these systems play a key role in climate change adaptation strategies, supporting the implementation of NbS and ecosystem-based approaches. The environmental impacts of EWS contribute significantly to sustainable development in flood-prone regions of developing countries.

Economic Outcomes

EWS can also deliver significant economic benefits by reducing costs associated with flooding. They enable communities to adopt resilience practices and preventive solutions, minimising impacts on local economies and infrastructure. These systems provide valuable insights and timely warnings that facilitate quicker recovery after hazard events. The economic value of EWS goes beyond immediate savings, offering at least a tenfold ROI, making them cost-effective for flood-prone developing countries. In this EWS, damage curves were integrated to quantify the impact caused by flooding events. For example, an inundation of one meter can lead to the loss of 50% of crops in the affected agricultural land, causing significant economic loss to farmers estimated at 50 Malawian Kwacha ($1.8) per square meter of agricultural land. By understanding the economic impact, these systems help make the case for the implementation of measures that will preserve livelihoods and maintain stability in vulnerable regions. They also enhance resource allocation for disaster response and long-term planning, contributing to overall economic resilience and sustainable growth amid increasing climate-related challenges.

Engaging with the community in Malawi, October 2023.

GEOSPATIAL DATA FOR EMERGENCY RESPONSE IN SOMALIA

Sector

Health

Resilience Phase

PREPARE **RESPOND** RECOVER ADAPT

Highlights

Healthcare | Safety | Capacity building

Project start/completion
2020

Location
Puntland, Somalia

Communities impacted
Rural and coastal

Hazards mitigated
Pandemic and Cyclone

Case study provided by:
This case study is provided by the Global Partnership for Sustainable Development Data, produced in collaboration with Puntland Statistics Department, UK Office of National Statistics, GRID3, Flowminder, and the United Nations Population Fund.

Global Partnership for Sustainable Development Data

Number of people made more resilient

4.3 million

LEARN MORE

In Puntland, Somalia, technology played a critical role in building community resilience against disasters and the COVID-19 pandemic. By leveraging GIS and satellite data, the Puntland Statistics Office (PSD) developed data-driven approaches to manage emergencies effectively. This report examines the technology's role in enhancing social, economic, and environmental resilience in the region.

ABOUT THE PROJECT

Puntland, a regional state in northeastern Somalia, faces unique challenges due to its predominantly nomadic population and a significant number of internally displaced people (IDPs). Access to reliable population data is limited, making planning and monitoring emergency responses difficult. When COVID-19 emerged in 2020, the need for accurate, real-time data became critical to managing the pandemic. Recognising this, the Global Partnership for Sustainable Development Data brokered partnerships between Puntland's Statistics Office, GRID3, the UK Office for National Statistics, and the UN Population Fund (UNFPA).

Over two months, GRID3 provided comprehensive GIS training and certification for statistics officers in Mogadishu and Garowe. The training enabled the Puntland Statistics Department to build a COVID-19 Data Hub, allowing departments to access and share critical information related to the pandemic, such as health facility locations and sanitation data. This newfound capacity also allowed the department to respond effectively to Tropical Cyclone Gati in November 2020. Using geospatial tools, they tracked the cyclone's path, assessed infrastructure impact, and mapped vulnerable populations, enhancing both pandemic and climate resilience.

Technology was central to building resilience in Puntland through several key components.

Geospatial analysis using GIS and satellite data enabled authorities to monitor environmental changes and emergencies in real time, allowing the Puntland Statistics Department to create precise maps, assess infrastructure damage, and track the movement of vulnerable populations. Data integration and visualisation through the development of the COVID-19 Data Hub facilitated the sharing of crucial information across departments. This hub allowed decision-makers to visualise and respond effectively to healthcare, sanitation, and demographic data, supporting informed planning and interventions for both the pandemic and climate-induced disasters. Additionally, the project's comprehensive training programme equipped local officials with skills in GIS software, data analysis, and real-world application, which proved vital during the COVID-19 pandemic and Cyclone Gati. This technology-focused capacity building demonstrated how skills development directly enhances community resilience in the face of various challenges.

By integrating technology into its emergency response systems, Puntland has laid the groundwork for a more resilient society, capable of responding to and recovering from both natural and human-induced crises.

OUTCOMES

Social Outcomes

The integration of technology into Puntland's emergency response systems had significant social outcomes. The GIS tools enabled authorities to identify cyclone-affected areas, allowing for swift evacuation and targeted aid distribution. By mapping infrastructure damage, such as destroyed homes and blocked roads, the department could prioritise recovery efforts and support displaced households, improving community safety and resilience.

The COVID-19 Data Hub also provided valuable insights into the locations and capacities of health facilities, ensuring a coordinated healthcare response during the pandemic. This information facilitated the targeted allocation of resources, improving healthcare access for communities.

The skills transferred through the GIS training programmes ensured that the knowledge remained within the community, enhancing long-term resilience as officials are better prepared for future emergencies.

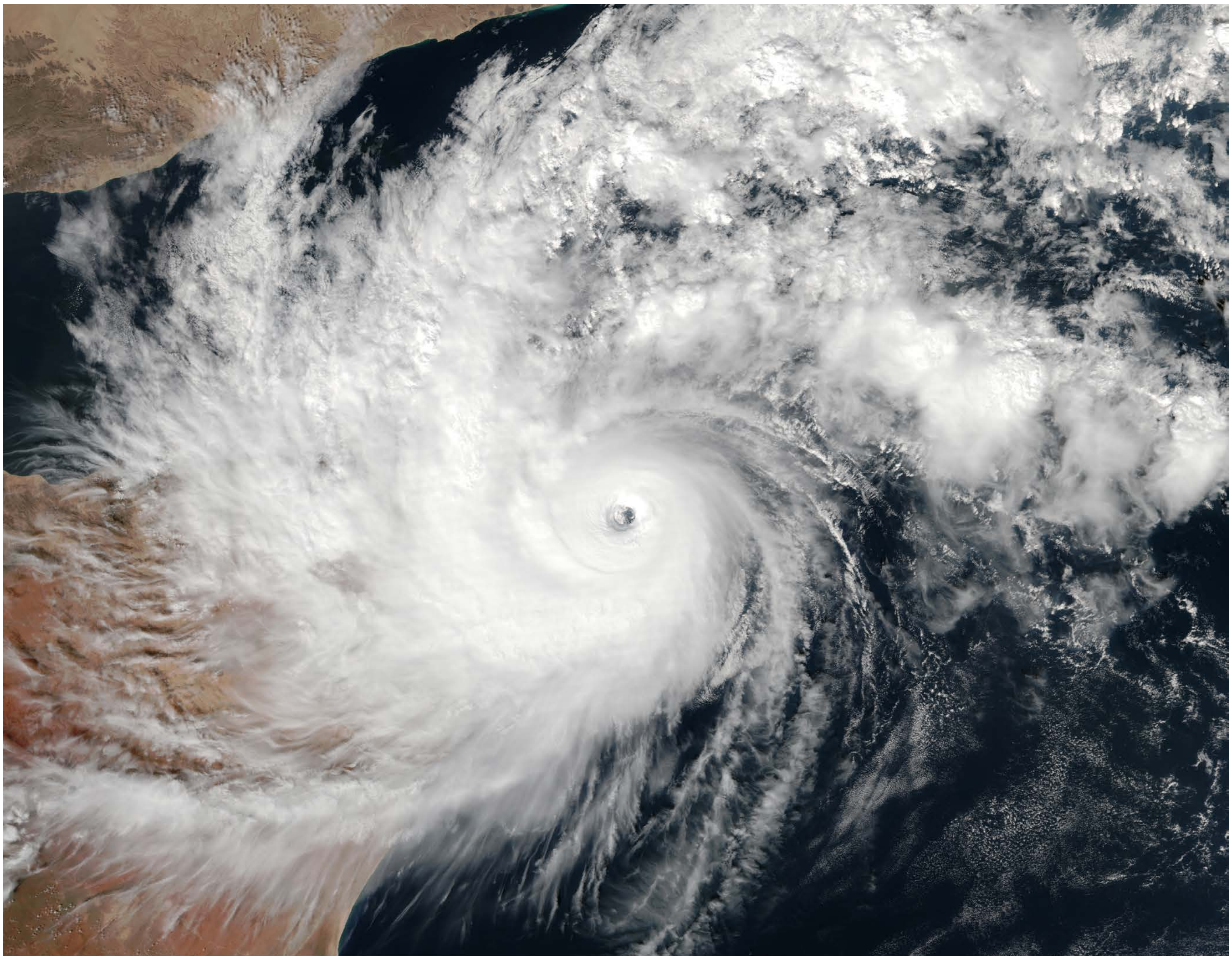
Economic Outcomes

With access to accurate, real-time geospatial data, the Puntland Statistics Department could deploy resources more effectively, reducing wastage and ensuring that aid reached the most affected areas promptly. This efficiency minimises economic loss during emergencies.

In addition, by identifying critical infrastructure damaged by Cyclone Gati, the government could expedite repairs to essential facilities like roads and health centres, promoting faster economic recovery. Restoration of infrastructure is crucial for communities relying on transportation networks for trade and livelihood activities.

"With the support of GIS tools and skills training, we were able to determine in real-time the cyclone-affected areas and intensity levels, as well as extract key disaster information about affected points of interest such as hospitals and schools, cropland, flooding, and so on. Without this information, the Government of Puntland would not have been able to anticipate and rapidly make targeted responses to the damage caused by Gati."

Abdifatah Mohamed, Director at Puntland Statistics Department.



HAITI RESPONSE PREPAREDNESS AND BUILDING RESILIENCE

Sector

Construction Built Environment

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Inclusivity · Safety · Capacity building · Community Engagement · Carbon mitigation · Job creation · Collaboration · Education

Project owners
Miyamoto International, USAID

Project start/completion
May 2018 – August 2019

Location
Haiti

Communities impacted
Urban, rural, and coastal

Hazards mitigated
Hurricanes/cyclones; earthquakes

Case study provided by:

miyamoto. EARTHQUAKE + STRUCTURAL ENGINEERS

USAID FROM THE AMERICAN PEOPLE

HAITI EARTHQUAKE AND HURRICANE RESPONSE PREPAREDNESS PROGRAM IN HAITI

Number of people made more resilient

600,000

LEARN MORE

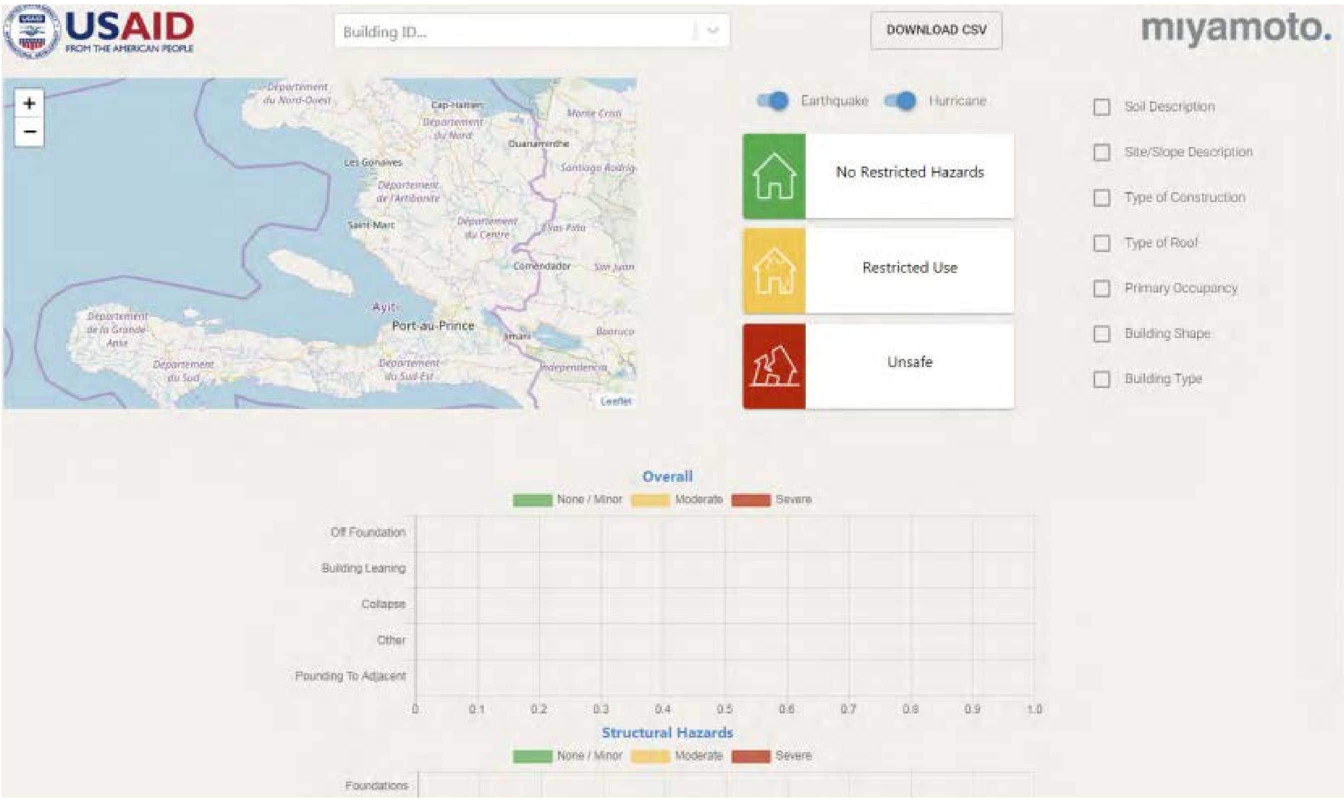
Recent disasters in Haiti, including the 2010 earthquake and hurricanes in 2016 and 2018, have devastated local infrastructure and highlighted the urgent need to build technical and institutional resilience. With funding from USAID, Miyamoto International has developed a mobile app that enables rapid post-disaster assessments of structural damage. Centralised data helps local authorities and humanitarian agencies make informed decisions on resource distribution and recovery efforts, helping to reduce the number of fatalities, injuries, and internally displaced people, and minimising social and economic disruption.

ABOUT THE PROJECT

Haiti is one of the poorest countries in the world, where informal settlements are widespread, and the real estate registry is not adequately maintained. The 2010 earthquake damaged nearly 300,000 houses in Haiti, highlighting critical concerns about the country's resilience to future disasters. This earthquake was a significant engineering disaster, revealing the urgent need to enhance building practices and materials, especially given Haiti's high seismic risk. Upgrading these techniques and expanding their use across major urban areas, while laying the groundwork for long-term sustainability, remains a top priority for disaster risk reduction (DRR).

The frequency and intensity of hurricanes, like Hurricane Matthew in 2016, and subsequent earthquakes, such as the one in 2018, have further emphasised the need for robust post-disaster assessment systems. Thousands of lives were lost due to collapsed buildings and infrastructure that might have withstood these disasters with proper building codes and engineering standards.

A user-friendly dashboard allows RDA data to be evaluated and disseminated to relevant authorities for decision-making.



In response to this, Miyamoto implemented the USAID/OFDA Earthquake and Hurricane Response Preparedness Program in Haiti to develop a technical platform for a post-disaster building safety evaluation system and advance the efforts to institutionalise this system. The technical platform utilises Miyamoto-certified engineers trained in Rapid Damage Assessment (RDA) methodology to conduct swift evaluations for both seismic and wind damages. As a critical response activity and first step toward recovery, damage assessments are typically carried out within the first few weeks following a disaster. To facilitate rapid assessment, a mobile application has been developed that allows certified engineers to quickly assess structural damage and categorise buildings using a colour-coded system: 'Red' (do not enter), 'Yellow' (repairs needed), and 'Green' (safe to enter). This mobile RDA method can be implemented within hours of a disaster, well before humanitarian aid reaches the country, providing early damage assessment results that serve as preliminary data sources for both immediate and long-term humanitarian needs.

All data collected is automatically synced and stored on a cloud platform with a user-friendly dashboard, where it can be evaluated and disseminated to authorities and other stakeholders who need to make quick decisions on resource allocation. The platform integrates data from various assessments, providing a comprehensive view of the damage across affected areas. The data was monitored and analysed with ArcGIS and PowerBI in real-time by Miyamoto international experts. Recurring errors were identified and addressed through timely and continuous communication with the team on the field. Through an algorithm linked to the database, damage and repair reports, including the material quantities needed to repair the building, were produced and made available for download by the homeowners through a QR code affixed to their building at the time of the visit.

After nearly a decade of lengthy damage assessment processes and relentless disasters, this mobile app allows certified engineers to rapidly assess structural damage and make life-saving decisions backed by data. By utilising real-time data like soil description, slope, type of construction, type of roof, primary occupancy, and building type and shape, the programme transforms how humanitarian aid and government resources are deployed after disasters, improving resilience and saving lives through informed data-driven decisions. The results of the RDA can offer detailed insights into the number of displaced families and the condition of infrastructure, enabling targeted assistance and strategic planning for both immediate response and long-term recovery.

The second core objective of the programme is to institutionalise this system. This involves outreach to key stakeholders, including relevant government ministries, the College National des Ingénieurs et Architectes d'Haiti (CNIAH – Board of National Haitian Engineers and Architects), public and private university partners, such as the University d'Etat d'Haiti and Quisqueya University, and private sector partners. Ongoing engagement and high-level support from the President's Office, the Prime Minister's Office, the Ministère des Travaux Publics, Transports et Communications (MTPTC), and other key government institutions built momentum around the programme that will be carried forward.

CNIAH was a key partner in this programme. From the early stages of planning, Miyamoto engaged with CNIAH to create a programme that would be sustainable, inclusive, and address gaps within the engineering and architecture industry as they relate to building better and DRR. Their support and active participation has positively contributed to the momentum behind the programme's main activities and its sustainability. CNIAH will take over the trainings on the RDA methodology, helping to ensure the training curriculum will continue to be utilised to increase the resilience of Haiti.

These critical activities are the first step in institutionalising a post-earthquake and post-hurricane damage assessment programme. By engaging with Universities, the private sector, and organisations from the international development sector, Miyamoto has communicated the importance of institutionalising the post-disaster damage assessment system and the critical role CNIAH plays within the engineering and architecture industry. This outreach, knowledge sharing, and capacity building was built upon in a follow-up project completed in 2021 which served to reinforce and strengthen local disaster risk management (DRM) capacity, further enhancing its institutionalisation and Haiti's preparedness for natural disasters.

ACHIEVED OUTCOMES

Social

The programme greatly enhances the social resilience of Haitian communities by prioritising safety and preparedness. By improving building codes and construction practices, the risk of structural collapse during natural disasters is reduced, thereby protecting lives and minimising injuries. This fosters a sense of security among residents, which is crucial for maintaining social stability in the aftermath of a disaster.

Through this programme, 179,800 buildings have been evaluated and approximately 10 million sqm of buildings have been assessed, with an average of 60 sqm per building. Approximately 600,000 beneficiaries have been reached through these activities.

The selection of high-quality materials significantly improves the resilience of post-earthquake construction in the region. Additionally, enhanced construction practices, including vertical reinforcement in walls and columns and detailed seismic design, result in structures that are more robust and resilient than those built before the 2010 earthquake. As observed in mason surveys, the overall construction quality has markedly improved due to better material selection and construction methods following the 2010 earthquake.

By quickly assessing and categorising damaged structures, the initiative facilitates faster recovery and a return to normalcy for internally displaced people and vulnerable groups. Families can safely return to their homes, reducing the psychological stress and social disruption caused by displacement. Schools and hospitals can resume operations more swiftly, ensuring continuity in education and healthcare services. Overall, the programme not only mitigates the immediate social impacts of disasters but also contributes to long-term community resilience by embedding a culture of safety and preparedness.

The programme has facilitated numerous training sessions for engineers, architects, and other professionals in Haiti. A total of 309 total people were trained under this programme, including eight women. Moreover, 151 engineers were trained and around 100 engineers now represent the Haitian government as the first hired engineers to be public officials to be placed in the Municipalities.

Participants have reported increased knowledge and skills in earthquake and hurricane preparedness, enabling them to contribute more effectively to DRR efforts in their communities.

Environmental

By promptly addressing issues such as debris clearance, the programme mitigates the long-term environmental impact of natural disasters. This proactive approach to environmental management ensures that ecosystems are preserved and that communities remain safe and healthy. Furthermore, the programme's emphasis on resilience and sustainability encourages the adoption of vernacular practices. By promoting green building standards and renewable energy solutions, the programme contributes to reducing Haiti's carbon footprint and supports global efforts to combat climate change. It also decreases carbon emissions related to transporting and manufacturing by using locally produced materials. Overall, the programme not only safeguards the environment but also fosters a culture of environmental stewardship, ensuring that Haiti's natural resources are preserved for future generations.

Economic

The programme is a significant economic initiative in Haiti, reducing the financial impact of disasters. It focuses on improving building codes and construction practices to minimise damage and reduce costs. The selection of quality materials and improved construction practices, such as vertical reinforcing and seismic detailing, have resulted in more robust structures compared to those built before the earthquake in 2010. This reduction in financial burden is crucial for the government and affected communities, allowing for more efficient resource allocation.

The initiative also stimulates economic growth by creating jobs in the construction and engineering sectors. As demand for skilled labour in implementing new building practices increases, more employment opportunities arise, boosting local economies. This job creation helps to alleviate poverty and improve the overall economic well-being of communities, contributing to a more stable and a prosperous society.

In addition, the programme leverages technology to optimise resource allocation and decision-making. This technological integration enhances the efficiency of recovery efforts, enabling quicker restoration of infrastructure and services, which is essential for maintaining economic stability and attracting investment. By promoting a more resilient built environment, the programme fosters investor confidence, encouraging economic development and ensuring a sustainable financial future for Haiti.

HARNESSING THE COMBINED POWER OF AI AND SOCIAL MEDIA FOR DISASTER RESPONSE

SHORT CASE STUDIES

The integration of AI-driven image filtering combined with the vast reach of social media addresses several challenges inherent in disaster response. First, it reduces the manual effort required to parse through vast amounts of social media posts and satellite imagery, enabling emergency responders to focus on critical incidents. Second, the use of natural language processing (NLP) techniques allows the AI models to extract location data from untagged posts, which is crucial in disasters where geotagging is not always available. Third, combining social media posts with satellite data allows for the creation of real-time maps that accurately reflect the progression of a disaster. These dynamic maps improve the ability of authorities to coordinate evacuations, assess damage, and deploy resources to areas in need.

INCIDENTS1M DATASET FOR INCIDENT DETECTION

The Incidents1M project, developed by MIT and the Qatar Computing Research Institute (QCRI), presents a significant technological advancement in the use of AI for disaster response, focusing on the creation of a large-scale dataset to detect in order to analyse disasters in social media imagery. As climate change intensifies the frequency and severity of disasters such as floods, wildfires, and storms, the ability to rapidly acquire, filter, and assess real-time information becomes critical for emergency response efforts. The Incidents1M dataset, which includes nearly one million images, allows AI models to be trained to detect incidents across multiple categories, improving the speed and accuracy of disaster management.

A key component of this project is the use of computer vision and deep learning models to automatically process large volumes of visual data from social media platforms. The reliance on social media is particularly beneficial during disasters as individuals post images and updates in real-time, often before official data sources can respond. The AI models developed through the project can filter out irrelevant information and prioritise actionable content, such as images depicting damage to infrastructure or hazardous conditions that require immediate intervention. This technology significantly enhances disaster resilience by providing emergency services with up-to-date, reliable data, thus improving situational awareness, resource allocation, and response times.

MIT CSAIL

QCRI
معهد قطر لبحوث الحوسبة
Qatar Computing Research Institute
جامعة حمد بن خليفة
HAMAD BIN KHALIFA UNIVERSITY

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ARTIFICIAL INTELIGENCE FOR DIGITAL RESPONSE

AIDR (Artificial Intelligence for Disaster Response) is a free and open-source software developed by QCRI that automatically collects and classifies tweets that are posted during humanitarian crises. There is far too much data produced via social media during crisis situations for humans to filter and organise it on their own. The data is also too rich and complex for machines to successfully process it. AIDR overcomes these challenges by combining human and machine intelligence.

Humanitarian or crisis responders can use AIDR to gather and classify tweets about a particular situation. AIDR has two key functions: Collector and Tagger. Using a list of keywords, hashtags and/or a geographical region of interest, users can begin to gather tweets using the Collector. In disaster situations, the Collector can filter tweets just like a regular search on Twitter. However, not all results will be relevant to disaster response or to the specific information needs of humanitarian organisations.

To organise the tweets, users can create different categories to label the information using the Tagger. While the Collector is a word-filter, the Tagger is a topic-filter. The Tagger classifies tweets by topics of interest, such as 'Infrastructure Damage', and 'Donations', for example. The classification is done automatically using machine learning models trained on a set of human-tagged items which are provided through MicroMappers, a crowdsourcing platform.

Once this is done, the Tagger automatically applies the classifier to incoming tweets collected in real-time using the Collector. All new tweets that relate to infrastructure damage (or another defined category) are automatically tagged and displayed on the Tagger, which can be used to power a live dashboard and/or crisis map.

In response to Pakistan's devastating 2022 floods, AIDR analysed over 9 million tweets to assess the immediate needs of the affected communities. This analysis identified critical shortages and prioritised essential resources such as food, water, and shelter. By leveraging social media data, AIDR provided timely insights that supported relief efforts, allowing for a more targeted and effective response to those in urgent need.

AIDR artificial intelligence for digital response

QCRI معهد قطر لبحوث الحوسبة Qatar Computing Research Institute جامعة حمد بن خليفة HAMAD BIN KHALIFA UNIVERSITY

LEARN MORE

KOMUNIDAD: AI FOR CLIMATE RESILIENCE

Sector

Telecommunications

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Community engagement | Coastal resilience | Carbon mitigation | Disaster management | Accessibility | Safety | Property protection

Project owner
Komunidad

Project start/completion
2021 – ongoing

Location
Philippines

Communities impacted
Urban, rural, coastal

Hazards mitigated
Extreme weather, flooding, droughts, storm surges, coastal flooding, coastal erosion.

Case study provided by:

komunidad

Number of people made more resilient

2 million
in the Philippines

100 Million
globally

LEARN MORE

RACE TO RESILIENCE

Komunidad's platform in the Philippines provides real-time weather monitoring and early warning systems to over 1,200 barangays, protecting two million people. It uses multi-source climate data and AI to enhance disaster preparedness, empowering local governments and strengthening climate resilience.

ABOUT THE PROJECT

Komunidad, a climate data and analytics software company, was launched in 2021 in response to the rising frequency and severity of climate-related disasters, particularly in Asia, which remains one of the most vulnerable regions to climate change. The World Risk Index has ranked the Philippines as the most at-risk country for three consecutive years since 2022. Addressing these challenges, Komunidad developed an all-in-one platform for Environmental, Social and Governance (ESG) and sustainability, climate risk, and social impact with an accessible, affordable, and user-friendly interface. The platform has been widely adopted in major cities in the Philippines showcasing its commitment to delivering climate resilience solutions at scale.

The Komunidad platform offers comprehensive tools for ESG and Sustainability Management, enabling businesses and communities to proactively address environmental and social challenges and track carbon accounting, sustainability reporting, and decarbonisation, all aligned with GHG Accounting standards. The platform provides high-quality carbon emissions data, ensuring precise and reliable reporting. It includes a marketplace for carbon offset projects and access to over 20,000 peril metrics, enabling users to conduct in-depth climate risk analyses and scenario modeling up to 2100. The platform also includes social impact tools for real-time weather monitoring and early warning systems (EWS), integrating multi-source climate data, including satellite imagery, sensor networks, and AI algorithms to enhance tailored insights for a specific location.

To make EWS more accessible, Komunidad launched Curbeet — an AI-powered app that incorporates early warning alerts, activity monitoring, lifestyle insights, quick SOS, safety tips, and collaboration tools for disaster preparedness.

By unifying data from multiple sources and using AI to process and analyse this information, Komunidad offers localised, high-quality, and actionable intelligence. This allows communities to monitor risks in real-time and efficiently deploy response strategies. The platform's AI capabilities extend to automated reporting and event-triggered alerts, ensuring that users receive relevant information promptly and in a format that is easy to understand.

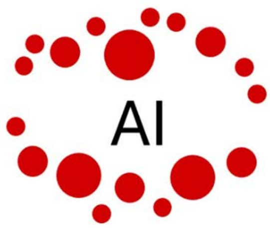
Additionally, the use of AI-enabled chatbots and SMS alerts makes the technology accessible to a broad audience, including those without smartphones. This inclusive approach ensures that EWS reach all community members, enhancing preparedness and resilience across diverse demographics and allowing communities to make informed decisions and take preventive action without the need for expensive infrastructure or sensor installations. Komunidad's solution is adaptable and scalable, making it suitable for urban and rural areas alike, including coastal and off-grid communities, demonstrating a scalable model for global climate resilience efforts.

Technology used by Komunidad

Legacy technology

- ✓ Distribute early warnings in local languages

Emerging technology



- ✓ Facilitate early warning distribution
- ✓ Rapidly collect and verify data on emergency services
- ✓ Enable safety chatbot

OUTCOMES

Social

Komunidad's platform has empowered local governments and communities to take proactive measures to safeguard lives and property. In the Philippines, the system currently protects over 1,200 barangays, including five major urban areas, covering a population of two million. The EWS delivers tailored alerts via SMS and social media platforms like Facebook, ensuring that critical information reaches users quickly, even those with basic mobile phones.

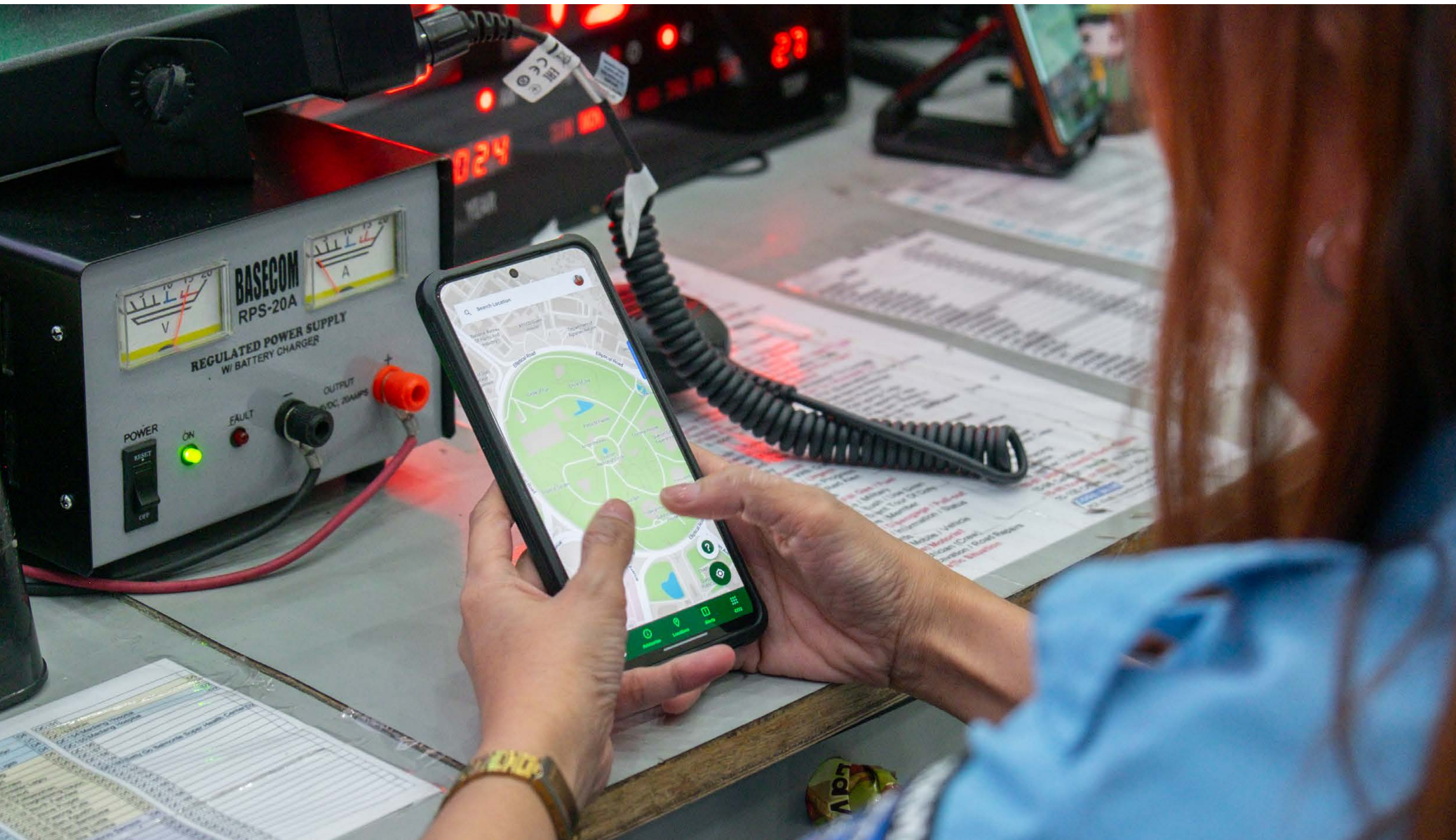
In collaboration with the Department of Information and Communications Technology, Komunidad piloted its technology on Calaguas Island, a remote, off-grid coastal community in the Philippines. This project allowed 4,000 residents to receive timely information about weather risks, showcasing the platform's ability to bridge the last-mile connectivity gap and support the most vulnerable populations. Through the GSMA Innovation Fund, supported by the Foreign Commonwealth and Development Office (FCDO) and Swedish International Development and Cooperation Agency (SIDA), nine municipalities in Siargao Island with a population of 150,000 also benefit from localised weather forecasts, enabling them to better prepare for extreme weather events.

Environmental

The deployment of Komunidad's platform has significantly enhanced the climate resilience of communities by providing localised, data-driven insights that enable effective DRM. By offering early warnings and forecasts for various hazards such as tropical cyclones, floods, and droughts, Komunidad reduces the risk of environmental degradation caused by extreme weather events. Their system supports sustainable land use planning, helping to minimise damage to natural ecosystems and resources.

Economic

Komunidad's technology has generated economic benefits by reducing the costs associated with extreme weather events. For local governments, the platform allows them to optimise their DRR strategies, minimising infrastructure damage and emergency response costs. Businesses, such as those in the energy and real estate sectors, use the system to manage operational risks, ensuring productivity and profitability despite adverse weather conditions. In the agricultural sector, Cambodian farmers utilise weather forecasts to plan planting and harvesting schedules, maximising crop yields and reducing financial losses.



LEVERAGING MOBILE TECHNOLOGY FOR EMERGENCY RESPONSE

Sector

Telecommunications

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Community engagement
Inclusivity
Community wellbeing
Disaster management

Project owners
GSMA and CARE Kenya

Project start/completion
Sept 2021 – ongoing

Location
Mandera and Garissa, Kenya

Communities impacted
Rural

Hazards mitigated
Drought

Case study provided by:

care

GSMA

Number of people made more resilient

25,372

LEARN MORE

RACE TO RESILIENCE

Partnering with CARE Kenya, the GSMA Mobile for Humanitarian Innovation (M4H) programme, funded by the UK Foreign, Commonwealth and Development Office, leverages mobile money solutions to provide effective cash assistance to vulnerable households. This report explores how technology enhances community resilience, particularly in the context of climate-related challenges, by improving efficiency, ensuring recipient dignity, and promoting financial inclusion.

ABOUT THE PROJECT

In response to the severe drought and food insecurity impacting the Horn of Africa from 2020 to 2023, CARE Kenya launched the Emergency Response to Drought and Food Insecurity (ERDFI) project, funded by the Bill & Melinda Gates Foundation. This initiative specifically targeted communities in Kenya's Mandera and Garissa counties, which are among the most affected regions. Following the Kenyan government's declaration of drought as a national disaster in September 2021, CARE Kenya adopted mobile technology to provide unconditional cash assistance to vulnerable households.

Leveraging mobile money platforms, particularly M-Pesa, CARE Kenya delivered cash assistance to 3,200 households, benefiting a total of 25,372 individuals. The shift to digital cash transfers was timely, especially amidst countrywide lockdowns due to the COVID-19 pandemic, which limited traditional forms of aid delivery. Collaborating with the GSMA M4H team, CARE Kenya aimed to document the implementation process, capturing successes, challenges, and lessons learned to enhance future cash transfer programmes.

OUTCOMES

Social

The integration of mobile technology in humanitarian assistance brought significant social outcomes for the affected communities. By utilising mobile cash transfers, CARE Kenya ensured that recipients received assistance efficiently, promoting recipient dignity and reducing the risk of fraud. The establishment of community-based cash transfer committees fostered local engagement and accountability, ensuring that the selection process for beneficiaries was transparent and inclusive.

A key aspect of the project was conducting rapid gender analyses to identify and address gender gaps in the cash transfer implementation. This consideration ensured that assistance reached all segments of the community, including marginalised groups. Additionally, the project's emphasis on recipient choice allowed beneficiaries to prioritise their spending based on their immediate needs, empowering them to make decisions about their cash utilisation and savings.

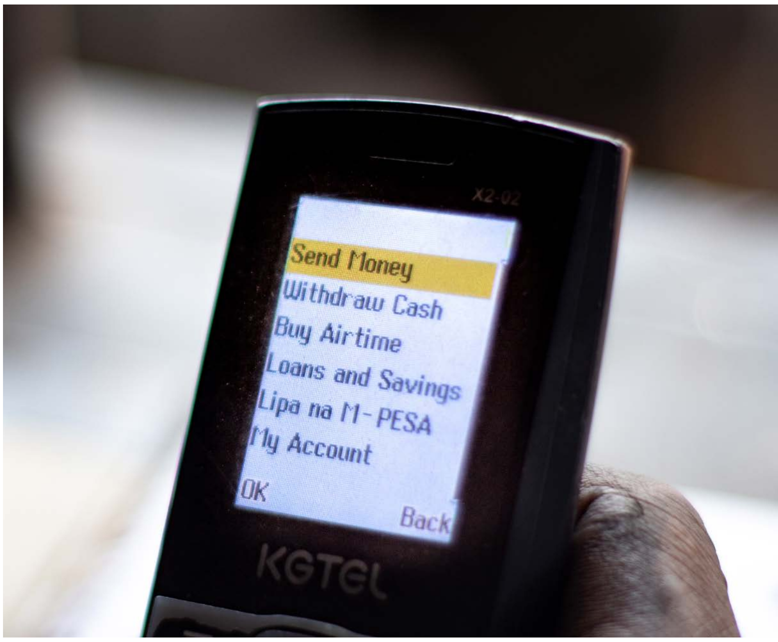
Post-distribution monitoring revealed a high level of satisfaction (90%) among recipients regarding their mobile money experience. This level of acceptance indicated that mobile cash transfers not only met basic needs but also contributed to recipients' overall sense of agency and control over their financial resources.

Establishing community-based cash transfer committees also promoted local involvement in the project, ensuring that the implementation process was inclusive and reflective of community needs. This engagement fostered accountability and built trust between the humanitarian organisation and the communities served.

Economic

The economic impact of digitising cash assistance through mobile technology was substantial. The shift to digital payments enabled CARE Kenya to deliver aid swiftly and securely, minimising logistical challenges often associated with cash distribution in remote areas. Mobile money facilitated better tracking of funds, improving accountability and transparency in the distribution process.

Moreover, the cash assistance provided a lifeline to vulnerable households, allowing them to meet their basic needs during a critical time.



With 98% of recipients reporting that they could satisfy their essential needs based on their priorities, the programme effectively contributed to household economic stability. Additionally, the programme fostered local economic activity as recipients utilised the cash to purchase food, water, and other essentials within their communities.

The focus on digital payments also set the groundwork for broader financial inclusion, as the recipients became more familiar with mobile financial services. However, the need for training on using mobile money highlighted the importance of enhancing digital literacy to maximise the economic benefits of mobile technology in future humanitarian efforts.

Environmental

While the primary focus of the ERDFI project was on addressing food insecurity and drought, the use of mobile technology indirectly supported environmental resilience. By improving the efficiency of cash distribution, the programme minimised the environmental footprint associated with traditional cash delivery methods, which often require extensive travel and physical logistics.

Furthermore, the digital cash transfer system allowed for better data collection and analysis regarding the impact of drought on communities. This data could inform future interventions and policies aimed at addressing the root causes of food insecurity and environmental degradation, contributing to long-term sustainability efforts.

MANAGING AUSTRALIAN BUSHFIRES WITH EARTH OBSERVATION DATA

Sector

Disaster Management

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Biodiversity Safety Property protection

Community wellbeing Disaster management

Project start/completion

2019 – 2020

Location

Australia

Communities impacted

Rural

Hazards mitigated

Wildfires

LEARN MORE

The 2019-2020 Australian bushfire season, commonly referred to as 'Black Summer', was a catastrophic environmental disaster that highlighted the increasing need for climate-resilient infrastructure. The use of Earth observation (EO) technologies and satellite imaging, played a pivotal role in managing and mitigating the devastating impact of the bushfires. These technologies offered real-time data for early fire detection, air quality monitoring, and post-fire recovery efforts, enhancing Australia's resilience to future climate-related disasters.

ABOUT THE PROJECT

During the 2019-2020 Black Summer bushfires in Australia, the Landsat programme provided essential satellite data for real-time monitoring and post-disaster assessment. The ground station, operational since 1979, is a crucial element in collecting EO data from Landsat 7 and 8 satellites, among others, and supports ongoing efforts to monitor environmental changes, such as those resulting from bushfires.

Throughout the Black Summer, a Hotspots system was instrumental in tracking and identifying areas of high infrared radiation, which indicated potential fire locations. By downlinking data from US satellites and Japanese weather satellites, the Hotspots system enabled the detection of active fires and provided this information to emergency services managers across Australia. Updated multiple times daily, this near-real-time data was made available within 30 minutes of each satellite pass, helping emergency responders identify high-risk areas quickly and direct their resources efficiently. This near-instantaneous data delivery played a critical role in informing decisions on evacuations, resource allocation, and hazard management to protect lives and infrastructure at the height of the disaster.

In addition to providing data during the active burning phase, Landsat and other EO systems offered detailed insights into the post-fire landscape. The satellite imagery allowed responders and analysts to map the burn extent, assess burn severity, and identify areas most heavily affected. This mapping of burn severity provided vital information for evaluating the extent of ecological and infrastructural damage. Furthermore, Landsat data contributed to the monitoring of water quality, particularly in reservoirs vulnerable to contamination from ash and debris runoff, and air quality, affected by the extensive smoke generated by the fires. These environmental data streams proved essential for both emergency response and public health, as they enabled targeted interventions and monitoring in regions where contamination posed additional risks.

The data collected also played a role in supporting Australia's carbon accounting through the Full Carbon Accounting Model (FullCAM). Landsat's long-term data archives, in combination with ground calibration data, informed this model to estimate the massive GHG emissions resulting from the fires, which totalled around 400 million tonnes of CO_2. FullCAM utilises spatially explicit data on land cover and forest disturbance events, including wildfires, to generate precise carbon estimates, allowing Australia to meet international reporting standards for GHG emissions. Landsat's ability to provide spatially accurate, long-term data was instrumental in this modelling, as it offered a comprehensive view of the burned areas and their associated emissions, which contributed to a satellite-era record of approximately 900 million tonnes of CO_2 emitted by Australia in 2019.

In the recovery phase, the Landsat archive continues to serve as a critical resource for tracking vegetation regrowth and ecosystem restoration. By comparing current post-fire landscapes with historical data, the Australian government and other research institutions can monitor vegetation dynamics and changes in land cover. This ongoing monitoring is essential for understanding the pace and extent of ecosystem recovery, helping guide reforestation efforts and identify regions where intervention may be necessary to support biodiversity and soil stabilisation. Landsat's consistent data stream allows for detailed monitoring of vegetation canopy cover and landscape transformation, which is essential for adaptive land management and ecosystem rehabilitation.

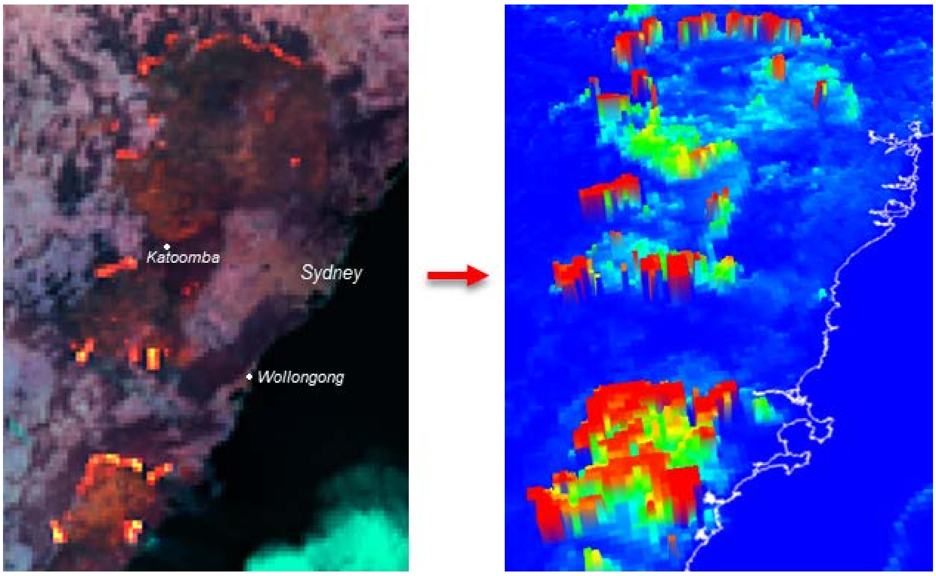


Image analysis turning Himawari-8 imagery into a hotspot probability map (red colours represent probabilities close to one). A threshold has to be chosen to define hotspots. © BigDataEarth.com 2020

OUTCOMES

Social

The near-real-time data provided by the Hotspots system played a significant role in protecting communities by alerting emergency managers to active fire zones and potential risks to inhabited areas. The prompt availability of satellite information supported rapid decision-making, enabling timely evacuations and directing resources to priority areas, ultimately enhancing community safety. Furthermore, post-fire monitoring of water and air quality helped protect public health by identifying areas at risk from smoke and ash contamination, informing health advisories and risk assessments. As communities recovered, Landsat data continued to aid in monitoring vegetation regrowth, supporting resilience efforts that aim to restore natural ecosystems and provide a safer, healthier environment.

Environmental

Landsat's extensive data archive is essential for monitoring Australia's post-fire ecosystem recovery. By comparing pre- and post-fire vegetation cover, Landsat enables a detailed analysis of recovery progress across affected regions, guiding restoration activities and biodiversity management. The data also helps track reforestation efforts, assisting in identifying areas where additional intervention may be required to restore habitats for endangered species. In addition, Landsat data contributes to accurate carbon accounting, with the Black Summer fires releasing an estimated 400 million tonnes of CO_2 into the atmosphere. By supporting sustainable land management and promoting habitat restoration, Landsat aids in rebuilding resilient ecosystems that can better withstand future climate impacts.

Economic

Landsat's data facilitated cost-effective disaster management by providing an efficient means to assess the scale of damage and guide resource allocation without the need for extensive ground surveys. The data enabled detailed mapping of burned areas, helping local governments and insurance providers to estimate economic losses accurately. In the long term, this data supports economic resilience by informing land management and reforestation efforts essential for maintaining agricultural productivity and protecting natural resources.

MAPPING THE INVISIBLE CITY

Sector

Built Environment

Resilience Phase

PREPARE RESPOND RECOVER **ADAPT**

Highlights

Inclusivity Safety Mobility

Project owners

The MIT Senseable City Lab and Washington Fajardo

Location

Rio de Janeiro, Brazil

Communities impacted

Urban

Hazards mitigated

Flooding, Landslides, Extreme heat

LEARN MORE

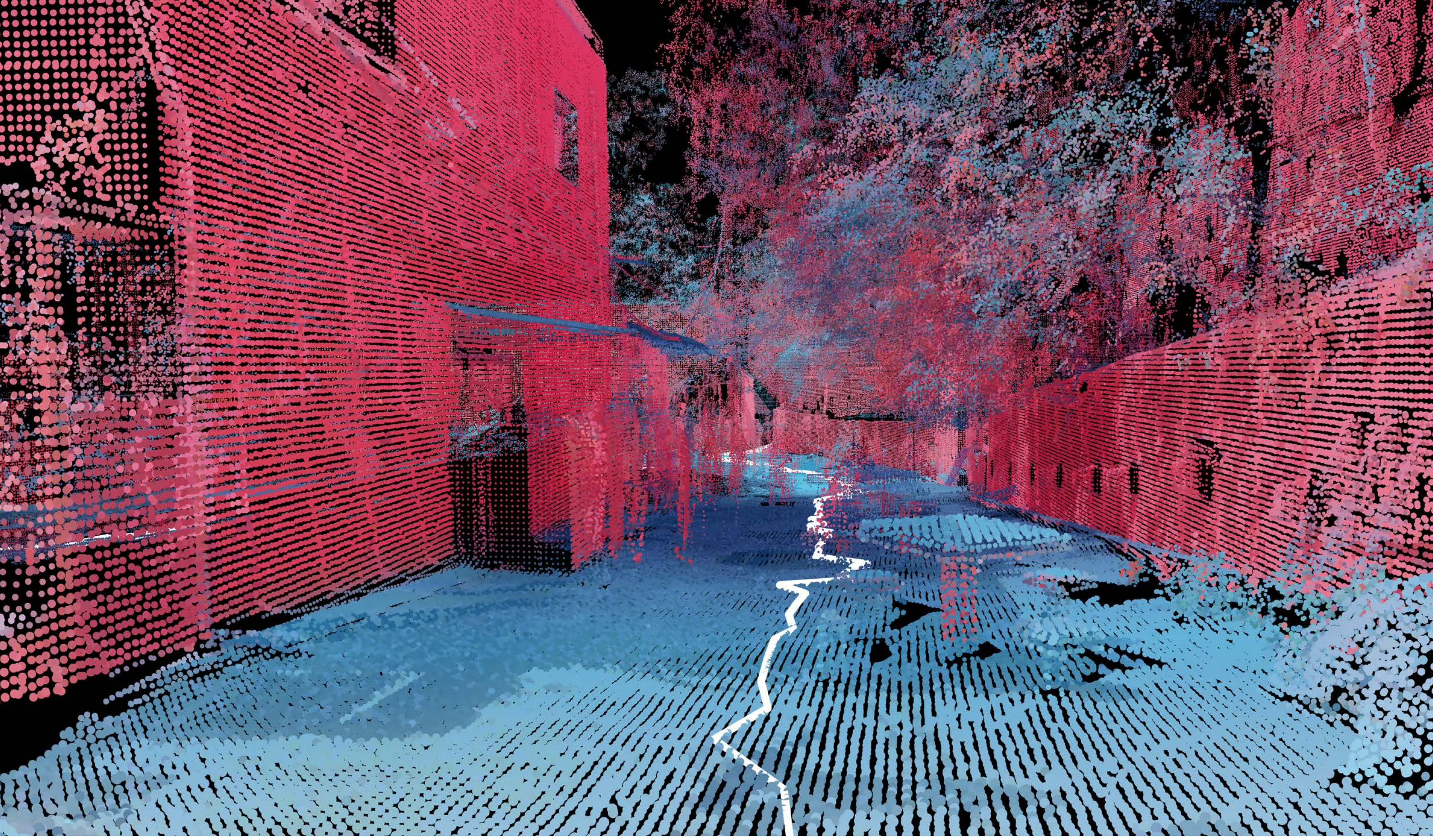
Favelas 4D is an innovative project by MIT's Senseable City Lab that utilises 3D laser scanning technology (LiDAR) to create a comprehensive digital map of Rocinha, Brazil's largest favela. The project aims to enhance climate resilience and support urban planning by making these communities visible, improving living conditions, and integrating them into formal urban frameworks.

ABOUT THE PROJECT

Rocinha, located in Rio de Janeiro, is the largest favela in Brazil, home to around 100,000 residents. Favelas, or informal settlements, typically grow in an unplanned manner, resulting in dense, maze-like structures that traditional satellite imaging cannot accurately map. As a result, these communities remain largely invisible in official records, often lacking access to formal services.

To address this issue, MIT's Senseable City Lab developed the Favelas 4D project. Using LiDAR technology, which emits pulses of infrared light to measure distances, the team created a precise 3D point cloud of the favela. With handheld LiDAR scanners, researchers navigated the narrow alleys and sloping terrain of Rocinha to collect 300,000 data points per second, capturing the intricate details of the 1.5 km^2 area. This approach bypassed the limitations of traditional satellite mapping, offering detailed insights into the favela's structure.

This data allowed the researchers to build a digital model of Rocinha that included information such as building density, street width, structural height, and elevation. This comprehensive 3D model reveals the favela's hidden dimensions and provides crucial information for climate resilience planning. By visualising the complex morphology of the settlement, the project can inform urban design strategies, and enhance the community's resilience against climate-related challenges. Urban designers and policymakers can use the model to pinpoint areas prone to flooding



or landslides, identify structural vulnerabilities, and plan for targeted infrastructure improvements. For instance, by analysing building density and topographical data, planners can design effective drainage systems to mitigate flood risks or implement slope stabilisation measures in landslide-prone areas.

OUTCOMES

Social

The Favelas 4D project has the potential to transform social dynamics in Rocinha by integrating the favela into formal city planning processes. By creating a detailed map of the area, the project makes the community visible to municipal authorities, paving the way for improved access to essential services such as water, waste collection, healthcare, and education. This visibility also grants residents recognition in the city's administrative system, promoting their urban rights and ensuring they are considered in policy decisions.

Moreover, by highlighting the unique building techniques favela residents have developed, the project offers an opportunity to learn from and integrate these bottom-up approaches into broader urban development plans. This fosters a sense of pride and ownership among residents, helping to build social cohesion and community resilience.

Economic

Mapping informal settlements like Rocinha can open new economic opportunities for residents. With access to formal city services and recognition in the official urban framework, residents can access better job opportunities, secure business permits, and receive support for local entrepreneurship.

Furthermore, improved infrastructure based on the insights from the 3D mapping — such as optimised transport routes or safer building practices — can enhance economic mobility by connecting residents to more economic centres and markets within Rio de Janeiro.

MELAMCHI FLOOD DISASTER IN NEPAL: DAMAGE AND RISK QUANTIFICATION

Sector

Water

Resilience Phase

PREPARE RESPOND **RECOVER** ADAPT

Highlights

Capacity building · Disaster management · Biodiversity

Project owners
The World Bank-GFDRR, NDRRMA, European Union, Ole Miss, Synspective

Project start/completion
June 2021 – June 2020

Location
Nepal

Communities impacted
Rural

Hazards mitigated
Landslides

Case study provided by:

GFDRR · Administered by THE WORLD BANK IBRD • IDA | WORLD BANK GROUP · Synspective · Ole Miss School of Engineering Geology and Geological Engineering · EUROPEAN UNION

Number of people made more resilient

~40,000

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RACE TO RESILIENCE

Following the Melamchi flood disaster in Nepal, a comprehensive project leveraging a combination of technologies has been implemented to assess and mitigate the risks associated with flooding and landslides. By integrating remote sensing, hydrological modelling, and community-based approaches, this case study illustrates how detailed data collection and analysis can significantly enhance disaster risk management strategies, ultimately fostering resilience in at-risk populations.

ABOUT THE PROJECT

The Melamchi flood disaster occurred on June 15, 2021, in the Indrawati basin of Nepal after several days of intense rainfall, culminating in catastrophic flooding along the Melamchi River. The heavy rainfall, exacerbated by rapid snowmelt, resulted in significant erosion of glacial deposits. Initial investigations revealed that a landslide had created a natural dam that pooled water upstream. When this dam collapsed, it unleashed a devastating torrent of water downstream, leading to widespread destruction in the Kathmandu Valley.

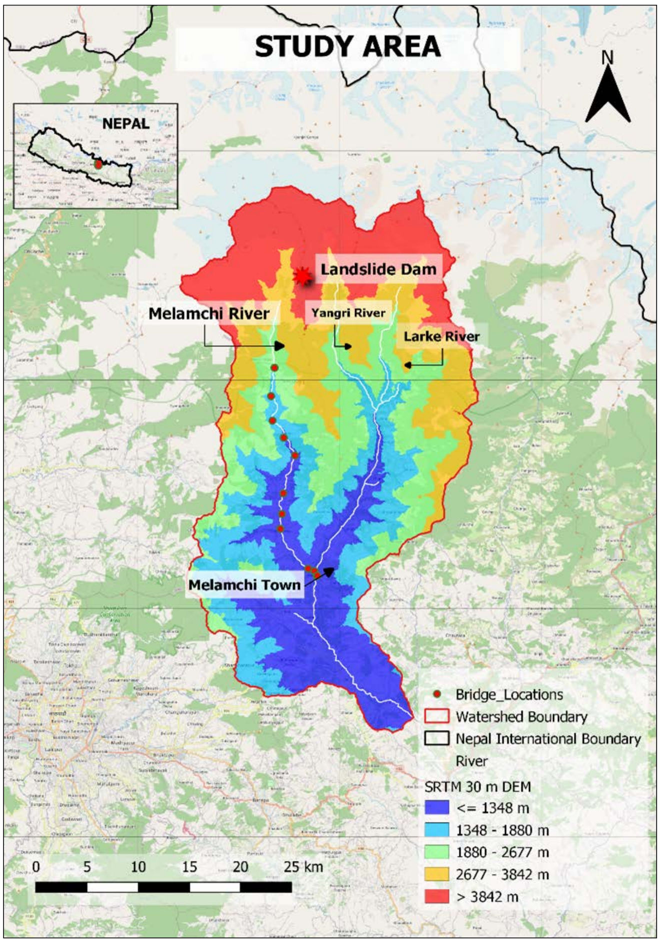
The impact was severe: the flood resulted in 99 fatalities, 19 individuals reported missing, 88 injuries, and affected 992 families. The economic toll was estimated at NPR 88 million ($654,960). To mitigate the impacts of future flooding, a project was initiated to employ advanced geospatial technologies for hazard management and risk assessment. The project's key components included UAV/drone-based surveys, flood modelling using the Hydrologic Engineering Center's River Analysis System (HEC-RAS), and satellite-based Synthetic Aperture Radar (SAR) for monitoring land displacement and identifying areas at risk of landslides.

The project employed a variety of advanced technologies to assess and manage the impacts of the Melamchi flood. A comprehensive UAV/drone survey was conducted between July 6 and August 30, 2021, covering approximately 100 km of the Melamchi River. The drone survey provided invaluable geospatial data, including high-resolution orthorectified images, 3D point clouds, and digital terrain models (DTMs). These outputs were essential for documenting the magnitude of erosion and sediment deposition along the river channel and facilitated the validation of flood models.

Flood modelling was carried out using HEC-RAS, a widely recognised tool for simulating river flows and flood events. The flood was modelled as a two-dimensional non-Newtonian flow, meaning the water carried a significant density of sediment and debris—specifically, a mixture comprising 10% debris in the water was selected for the final dam breach model. This choice accurately reflected the reality of the Melamchi flood, where large amounts of sediment and boulders were transported downstream. The rainfall data utilised for the model were collected from NASA's Global Precipitation Measurement (GPM), providing real-time precipitation data that was critical for simulating the flood response in the watershed.

In addition to hydrological modelling, GIS technology was extensively employed for both damage assessment and future risk planning. GIS platforms facilitated the integration of diverse datasets, including satellite imagery, drone data, and topographical information, enabling the creation of detailed flood hazard maps. These maps displayed the extent of the damage and identified areas at risk of future flooding. GIS tools were also used to overlay flood extent maps with infrastructure data, quantifying damage to critical facilities such as bridges, roads, and buildings. This detailed analysis was crucial in identifying regions of significant erosion and sediment deposition, which posed ongoing threats to infrastructure stability.

Sentinel-1 satellite SAR data was utilised to perform Interferometric Synthetic Aperture Radar (InSAR) analysis, mapping land displacement over time. The InSAR analysis used data collected from April 2017 to June 12, 2021, assisting in the identification of multiple hotspots vulnerable to ground movement. This data proved invaluable for disaster risk managers and local authorities, highlighting the potential for new geohazard risk management practices.

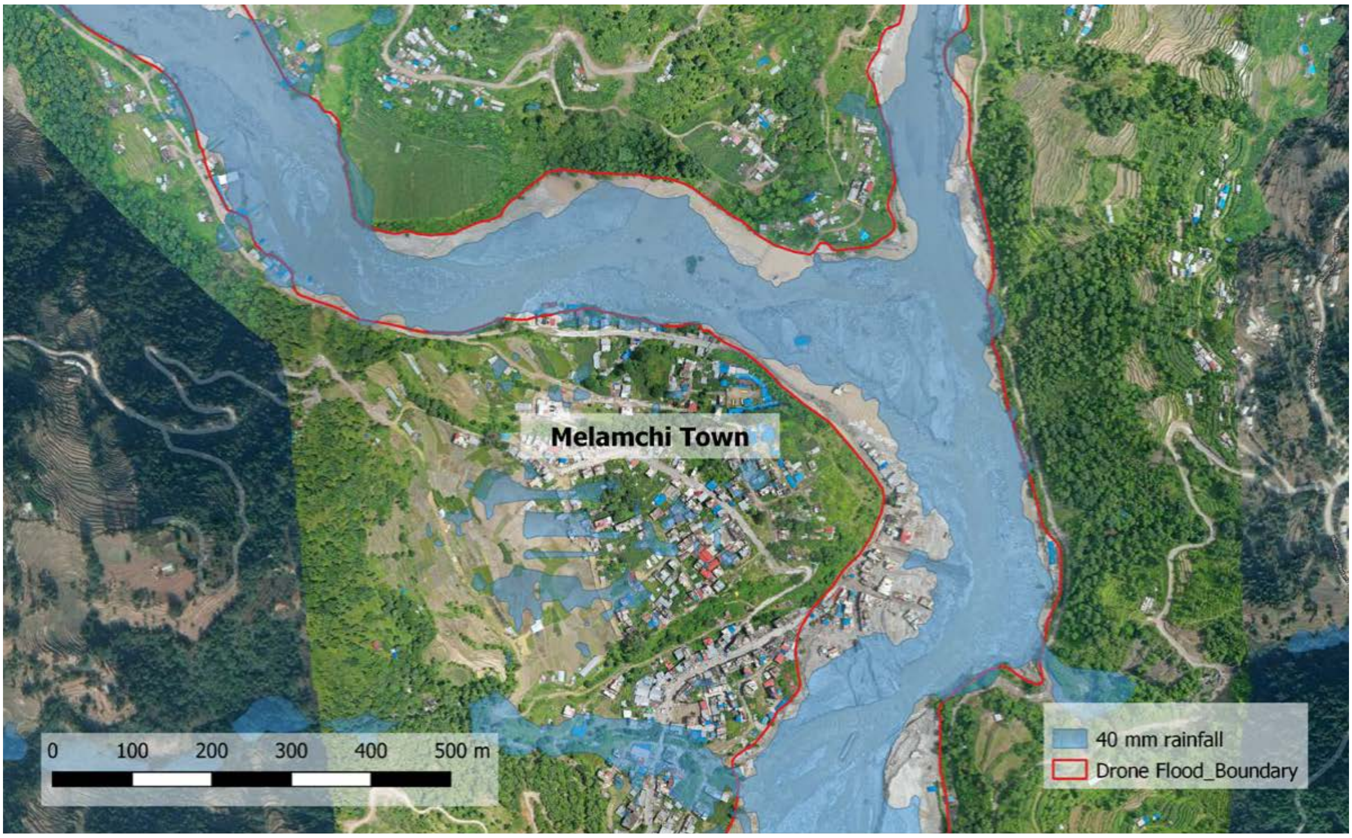


OUTCOMES

Social

The project has significantly contributed to enhancing community resilience against flooding and landslides. By employing a participatory approach, local residents were involved in the project from its inception. Training sessions were conducted to educate community members about using the new technologies for environmental monitoring and flood risk assessment. Approximately 200 community members participated in workshops that covered topics such as interpreting flood models, understanding the role of drones in disaster management, and implementing early warning systems based on real-time data.

This has led to increased awareness of local flood risks, enabling communities to better prepare for future events. The training has fostered collaboration among residents, local authorities, and technical experts, creating a network of informed individuals who can share knowledge and strategies to mitigate disaster impacts.



As a direct result, the community reported a 40% increase in preparedness levels, with households implementing measures such as improved drainage systems and flood-resistant infrastructure.

Economic

From an economic perspective, the project has facilitated effective resource allocation for reconstruction and recovery efforts. By utilising the data collected through drone surveys and flood modelling, authorities were able to identify areas that suffered the most damage and those requiring immediate attention. This targeted approach allowed for the most efficient use of economic resources, minimising waste and maximising the impact of reconstruction efforts.

The project also played a crucial role in developing a hazard assessment framework that has been used to create an insurance scheme for local businesses. This scheme aims to protect SMEs from future economic losses due to flooding and landslides. Following the flood, 75% of surveyed businesses expressed confidence in their ability to recover financially, thanks to the safety nets established through this project. The anticipated increase in economic stability is expected to contribute to the overall resilience of the local economy.

Environmental

Environmental benefits have been a key outcome of the project, which focused on monitoring and managing the natural landscape in the aftermath of the flood. The integration of drone surveys and SAR analysis provided vital data on land displacement and sediment transport, informing strategies for ecosystem restoration and protection. The drone survey yielded various products, including georeferenced orthorectified images, 3D-point clouds, and DTMs, which were instrumental in assessing changes in the river's morphology.

The project identified several hotspots vulnerable to landslides and erosion, which informed targeted conservation efforts, such as reforestation initiatives and riverbank stabilisation projects. This ecological restoration not only aims to mitigate future flooding impacts but also enhances biodiversity in the region. Monitoring efforts indicated a 20% increase in vegetation cover in previously eroded areas due to these interventions.

NEW BULLARDS BAR DAM, CALIFORNIA

Sector

Water

Built Environment

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Collaboration Safety Ecological uplift

Project owner
Yuba Water Agency

Location
Camptonville, California, USA

Communities impacted
Rural, urban, coastal

Hazards mitigated
All hazards

Case study provided by:

Bentley

Number of people made more resilient

80,000

LEARN MORE

RACE TO RESILIENCE

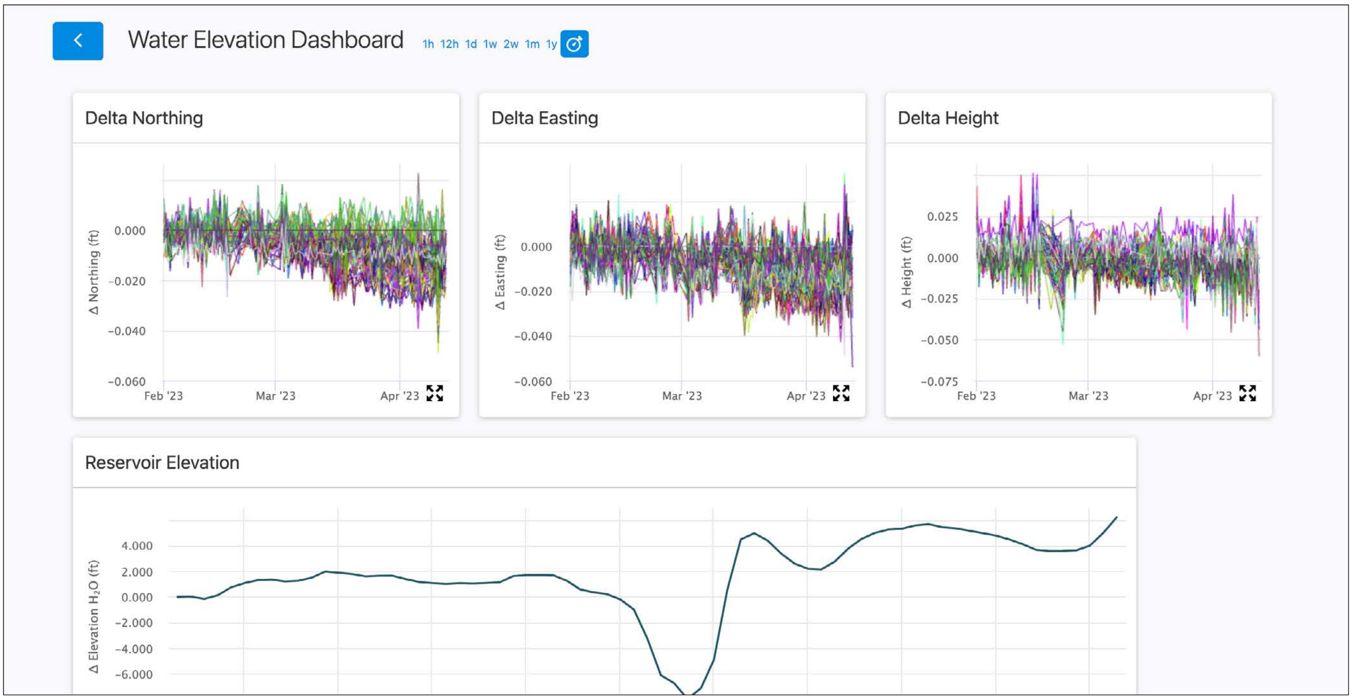
The New Bullards Bar Dam project in Yuba County, California, focused on improving dam safety and operational efficiency through advanced technological solutions. Yuba Water Agency has enhanced its inspection and monitoring capabilities by integrating drone surveys, IoT sensors, and AI-powered analytics, ensuring the dam's resilience and safety in the face of evolving environmental challenges.

ABOUT THE PROJECT

The New Bullards Bar Dam is a lifeline for the community it serves. Standing 645 feet tall, the dam is the second tallest in California and a critical piece of infrastructure, reducing flood risks, generating 340 megawatts of clean hydropower, and ensuring water reliability for the region. It also functions as a popular recreational haven, boasting miles of shoreline, hiking trails and campsites. However, the dam increasingly faces heightened risks due to more frequent and intense extreme weather events caused by climate change.

To address this, Yuba Water Agency embarked on a project focused on improving the dam's safety and operational efficiency through advanced technological solutions. Until recently, the dam relied on an outdated system that required time-consuming, costly, and hazardous manual data collection from 11 sensors that covered only a portion of the dam. This system not only posed safety risks for workers accessing the site but also lacked sufficient survey points, making effective condition monitoring a challenge.

Given the dam's age and the growing frequency of extreme weather events, this project sought to modernise the dam by replacing the outdated monitoring system with one designed to remotely capture and visualise real-time data while automating alerts and reports of potential issues. Yuba Water Agency implemented a new system, powered by



iTwin IoT Dashboard

Bentley System's Dam monitoring solution, that is remotely operated and continuously collects data from 83 sensors installed across the face of the dam. The sensor data is transmitted back to a cloud-based iTwin Internet of Things (IoT) platform and is incorporated into a 3D digital twin model of the dam that provides a comprehensive view of the dam within its geospatial context.

To create the digital twin model, Yuba worked with iTwin Ventures portfolio company, Niricson, to capture a 3D reality mesh from thousands of drone-captured images and process it in iTwin Capture. The photorealistic model was then uploaded to the iTwin IoT platform where the real-time sensor data enhances the digital twin and reflects what is going on in real time.

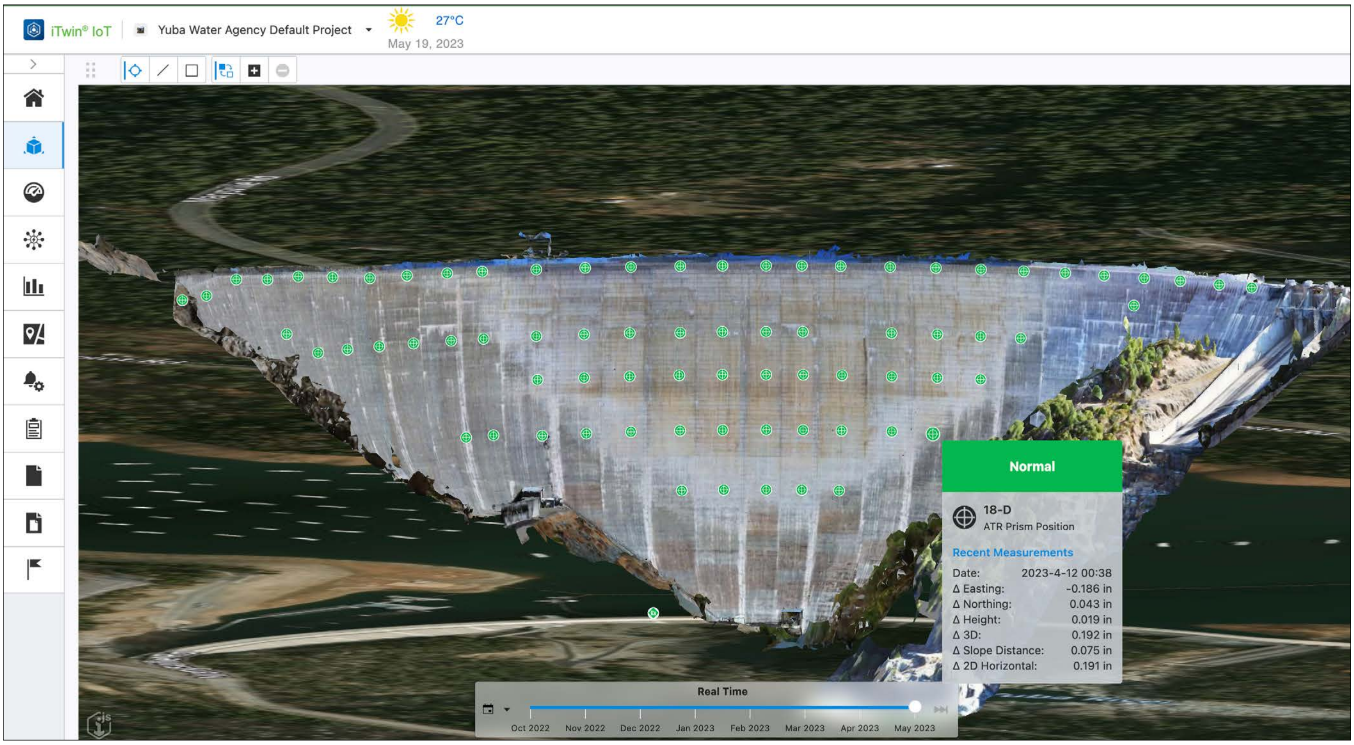
Compared to its previous manual monitoring system, the new system provides 1,000 times more data monitoring points a week, providing far greater insights into the dam's structural integrity at a given moment. Along with day-to-day monitoring, it will also provide a picture of the dam over time, as well as real-time readings during inclement weather or emergencies, such as earthquakes, allowing for rapid responses to potential issues.

The integration of IoT sensors and AI allowed for the remote and automated detection of structural vulnerabilities, such as cracks and deformation. This enhancement not only minimised the risks of dam failure but also improved the safety of inspection teams by eliminating the need for personnel to access hazardous areas directly. As a result, the project reduced data collection time from a week to just minutes, offering a substantial ROI.

The project overcame challenges such as steep terrain, securing necessary permits, and ensuring the safety and functionality of survey equipment in harsh environments. Ultimately, the updated system was put to the test and successfully confirmed the dam's safety following a 5.4 magnitude earthquake in June 2023, demonstrating its resilience and the effectiveness of integrating digital twin technology for infrastructure management.

This digital transformation allows for real-time data visualisation and monitoring of deformation patterns, enabling more precise and timely maintenance decisions. The adoption of AI further optimised crack detection and issue identification, automating alerts based on pre-set thresholds for early intervention.

The New Bullards Bar Dam project exemplifies the use of cutting-edge technology to build resilience in critical infrastructure. By harnessing this technology, Yuba Water Agency has reduced monitoring costs while drastically improving the efficiency and accuracy of inspections. The project demonstrates the advantages of incorporating IoT, AI, and digital twins into infrastructure management, ensuring the dam's resilience against the increasing impacts of climate change and extreme weather events.



iTwin IoT Digital Twin view of Reality Mesh

OUTCOMES

Social

The project enhanced public safety by providing advanced monitoring capabilities that detect potential structural issues during extreme weather events and seismic activity. The technology verified the dam's integrity after an earthquake, ensuring the protection of the surrounding community. Moreover, by automating data collection, the project significantly improved worker safety, eliminating fall hazards associated with traditional inspection methods in difficult-to-reach areas.

Environmental

Environmentally, the New Bullards Bar Dam contributes to the region’s sustainability by generating clean hydropower and supporting the ecosystem through reliable water management. The real-time monitoring system aids in early issue detection, preventing structural failures that could negatively impact the local environment. The use of drones and digital twins further highlights the project’s commitment to reducing its environmental footprint and maintaining ecological balance.

Economic

The project delivered significant cost savings by streamlining and automating data collection, minimising the need for manual inspections, and improving efficiency. Bentley System’s iTwin IoT software enabled more precise data collection, enhancing risk assessment and decision-making. These efficiencies translated into optimised resource allocation, better financial management, and long-term savings for Yuba Water Agency. The improved system has also led to a notable decrease in downtime and failures, enhancing operational efficiency. This transformation has not only saved valuable hours weekly but has also streamlined workflows and increased overall productivity.

PARTICIPATORY MAPPING IN CLIMATE RESILIENCE TECHNOLOGY

SHORT CASE STUDIES

Participatory mapping has emerged as a critical tool in enhancing the climate resilience of infrastructure, especially in flood management and urban planning. This technology involves communities directly in data collection and mapping processes, allowing for the integration of local knowledge and perspectives into decision-making. Through participatory mapping, communities become actively involved in identifying areas vulnerable to flooding and devising mitigation strategies. Central to this approach is the use of geospatial data platforms which amalgamate data from various sources to create comprehensive maps that inform and guide resilience efforts.

Participatory mapping methodologies often utilise a combination of digitised flood data and community input gathered through surveys, workshops, and public meetings. This data is then integrated into a GIS database, which serves multiple purposes. The database not only identifies urban areas at risk but also suggests locations where mitigation and adaptation strategies, such as sustainable urban drainage systems (SUDS), could be implemented. These maps foster community awareness, facilitate stakeholder engagement, and support urban planning. They serve as dynamic tools that allow urban planners to respond proactively to evolving flood risks and urban development patterns.

A key advantage of participatory mapping is its flexibility. It allows for updates as new data becomes available or as environmental and urban conditions change, ensuring that the maps remain relevant and accurate over time. The technology also accommodates a variety of stakeholders, incorporating the needs and insights of different demographic groups within a community. By doing so, it ensures that flood management strategies are both socially accepted and environmentally effective.

This section explores three case studies where participatory mapping and crowdsourced crisis mapping have been utilised to bolster flood resilience and infrastructure management.

ENHANCING FLOOD RISK RESILIENCE IN GENOA, ITALY

Participatory mapping was put into practice in Genoa, where it aimed to improve the city's SuDS to increase flood resilience. Research conducted in the Sampierdarena district of Genoa, Italy, utilised a GIS database combining digitised flood data and local community input gathered through surveys, workshops, and meetings. This approach was instrumental in identifying urban areas vulnerable to flooding and highlighting locations for potential mitigation strategies.

Throughout the study, various measures were taken to include perspectives of older citizens, ethnic minorities, and those speaking other languages. The GIS database created through this process became a valuable tool for flood risk management and fostering long-term community stewardship over local environments. By integrating participatory mapping into urban planning, the study demonstrated the potential of this technology to build social cohesion and enhance flood resilience while supporting environmental sustainability.

LEARN MORE

BACK TO INDEX PAGE

CRISIS MAPPING AND CROWDSOURCING FOR FLOOD MANAGEMENT IN CHENNAI

In December 2015, Chennai experienced its heaviest rainfall in over a century, resulting in widespread flooding. For residents and responders to react effectively, reliable data was needed on flooded streets and inundated areas — a resource that was initially unavailable.

Crisis mapping, which involves real-time data visualisation using inputs such as satellite imagery, social media reports, and local observations, played a crucial role in managing the emergency. A rapid response project utilised OpenStreet Map to fill data gaps. Crowdsourcing enabled residents to report areas that were flooded by zooming in on the map and clicking on the relevant area. Waterlogged points, subways, tunnels and flyovers were all marked, in addition to flood relief centres. Once reported, flooded areas turned pink, allowing citizens and responders to react accordingly. In two days, over 4,000 roads were reported as inundated.

The project owners merged collected data with other key data sources. The map consists of a base layer of low-lying areas created using elevation models from ISRO and NASA, and inundated areas from UNITAR. The map interactivity was built using Mapbox GL and was hosted on GitHub.

Chennai faced further severe flooding events in 2022 and 2023. Crowdsourcing was once again used to capture real-time data and inform emergency responses. The Indian Institute of Technology Madras (IIT-M) Center for Innovation developed a crowdsourcing initiative to collect real-time information on areas affected by waterlogging or flooding. Initially developed in response to a 2021 monsoon, the model was revived and improved during the 2022 floods.

IIT-M developed a website that allowed residents to mark water levels relative to a person or vehicle such as a car or bicycle, allowing responders to visualise the risk without having to physically measure flood levels, which can be time-consuming and dangerous. Residents were able to share data on waterlogging or flooding through WhatsApp or on a dedicated website in both English and Tamil. The project used the Risk Map, a free platform developed by the Urban Risk Lab at MIT to harness civic input for collective disaster management.

Public participation was critical in this crisis mapping effort, allowing responders to access near real-time information from the ground. Since 2015, improved access to social media and the internet has broadened the reach of crowdsourcing, allowing more people to contribute. The IIT-M team plans to use the data to analyse why certain locations get inundated, the frequency of inundation and other critical factors. This analysis aims to inform more effective preparation and response strategies for future flooding, as well as suggest remedial measures to the government.

Location
Chennai, India

LEARN MORE

MAPPING TROPICAL STORM ANA AND CYCLONE GOMBE IN MALAWI

In 2022, the Humanitarian OpenStreetMap Team (HOT) led a project in Malawi to map regions affected by Tropical Storm Ana and Cyclone Gombe. These storms caused extensive flooding and damage, particularly in the Chikwawa and Nsanje districts. HOT aimed to gather geospatial data to support early recovery efforts and enhance long-term disaster resilience.

Using satellite imagery combined with local knowledge, HOT volunteers and community members worked together to map flood extents, damaged infrastructure, and at-risk communities. This data was uploaded to OpenStreetMap, a public and open-source platform, allowing emergency responders, NGOs, and government agencies to access and utilise the information for planning recovery and humanitarian efforts.

The project emphasised local involvement, with HOT training community members as mappers. This not only ensured the accuracy of the data but also empowered local populations, giving them the skills and knowledge needed to respond effectively to future disasters. The data collected was crucial in guiding the efficient distribution of aid, reconstruction of infrastructure, and improving disaster preparedness plans for subsequent storms.

Humanitarian OpenStreetMap Team

Open Mapping Hub EASTERN & SOUTHERN AFRICA

LEARN MORE

Emily Mbobo, Eneless Peterson, and Alick Nsona, community committee members for disaster management in Chikwawa village, use maps to help with disaster response and mitigation decision-making . © Pauline Omagwa

RAPID DIAGNOSTICS OF SCHOOL INFRASTRUCTURE IN BURKINA FASO AND SENEGAL

Sector

Construction

Education

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Community engagement | Community wellbeing | Inclusivity | Education | Safety | Disaster management | Mobility

Project owners
The World Bank's Global Program for Safer Schools, and the Japan-World Bank Program for Mainstreaming Disaster Risk Management in Developing Countries

Project start/completion
Sept 2022 – Dec 2023

Location
Burkina Faso and Senegal

Communities impacted
Urban, Rural, Coastal

Hazards mitigated
Flooding, Extreme Wind, Extreme Heat

Case study provided by:

GeoHazards International, GRETECH, Woodwell Climate Research Center, GFDRR, The World Bank

Arches Etudes Senegal

Due to the sensitive nature of education facilities in Burkina Faso's ongoing conflict, public information about this project has been kept to a minimum.

GeoHazards International (GHI), Woodwell Climate Research Center (Woodwell), and local consultants conducted rapid diagnostics of school infrastructure in Burkina Faso and Senegal to identify the main factors that place school infrastructure at risk from climate stress and natural hazards, and to understand the overall management and context within which school infrastructure is planned, designed, built, operated, and maintained.

ABOUT THE PROJECT

Burkina Faso is exposed to significant climate and hydrometeorological hazards due to its location in and south of the Sahel. It is also in the midst of ongoing violent conflict affecting multiple Sahel countries, in which terrorist organisations have specifically targeted schools. Senegal is located at the western end of the Sahel, one of the world's most climate-vulnerable regions, and its extensive river deltas are exposed to sea level rise and flooding according to analyses by USAID, UNHCR and partners. Conflict in Burkina Faso is creating the most significant challenges and disruption to education there, but in both countries, natural hazard events and climate-related risks can and will continue to disrupt education by damaging school infrastructure and negatively impacting the learning environment. The economic losses due to damage also place strains on public financing. In both countries, recurrent flooding and extreme heat, which are both expected to increase with climate change, already affect operations in some schools. Future climate projections indicate that heat stress will likely affect instruction time across a more extensive geography in both countries and for longer periods.

Integrating climate modelling, resilience engineering, school architecture, and disaster management, the project team collected and analysed geospatial data on school infrastructure and hazards as part of a

Mature trees provide a cooling space at a school in Senegal

rapid diagnostic of school infrastructure that provided detailed recommendations for each country. The diagnostic followed the World Bank's Roadmap for Safer and Resilient Schools (RSRS) methodological framework to ensure all relevant aspects related to school infrastructure safety and resilience were systematically addressed. Developed by the World Bank's Global Program for Safer Schools, the RSRS is a step-by-step guide that supports governments and task teams in designing school infrastructure plans to make schools safer and more resilient at scale.

Findings and recommendations were based on a desk review of existing information, stakeholder consultations, modelling of key climate stresses and site visits at 20 schools with 41 buildings in Burkina Faso and 19 schools with 71 buildings in Senegal. Data on structural vulnerabilities, building conditions, energy efficiency, and the learning environment were collected using standard questionnaires in the ArcGIS Survey123 app.

Climate modelling was prepared by Woodwell using downscaled regional and global climate models. Extreme heat and heat danger analyses used daily temperature data from 16 CMIP6 models (CMIP6 is an international climate modelling project) under the ssp585 scenario (which has the most warming among the set of standard climate scenarios used in CMIP6), bias-adjusted and downscaled. The Heat Danger Days analysis also used bias-adjusted and downscaled dew point temperature data. Water scarcity, water stress, and extreme precipitation were estimated using Aqueduct combined with internally developed models.

Key recommendations related to modelling and technology include:

- The better integration of flood hazard maps and modelling (including for coastal flooding/hazards for Senegal), which should include projected impacts of climate change, in school siting decisions and GIS-based risk analysis at current sites;

- Identification of data necessary for adaptation decision-making (for example, temperatures, rainfall, flooding, and their impacts on school operations) and developing arrangements and systems for collecting, sharing, and utilising data;
- Utilisation of building-level school facility data to develop a climate adaptation programme that replaces ageing, leaking metal roofs with materials that provide better thermal performance, improves the learning environment and encourages shade tree planting, among other interventions.

These recommendations aim to increase the climate resilience of school infrastructure, particularly to reduce future loss of instruction time due to extreme heat, and enhance adaptation investment in existing schools by the respective governments, The World Bank, and other financial and technical partners.

Climate modelling was essential in determining the potential future impacts of extreme heat on instruction time and developing the diagnostics' primary recommendations to invest in a climate adaptation programme to make schools more resilient to heat. The project also recommended a portfolio-level GIS analysis of school exposure to flooding, and in Senegal, to coastal risks once school geolocations and hazard maps were made available. At the time of the rapid diagnostic, efforts to geolocate government schools were either ongoing or planned in both countries, and very detailed flood hazard maps were being developed in the highest-hazard areas in Senegal. As a result, high-quality mapping and GIS analysis of flood risks to schools will be possible in the near future. GeoHazards International has carried out similar GIS-based analyses of flood hazards for schools in Haiti, where both geolocation data and detailed flood hazard maps were available.

Students tend to recently planted trees at a school in the Siné-Saloum Delta in Senegal, located in a fishing community only accessible by boat and vulnerable to sea level rise.

INTENDED OUTCOMES

Social outcomes

Projections by Woodwell indicate significant increases in extreme heat and heat danger days ('feels like' temperatures) in both countries that are likely to result in school closures or the restriction of instruction time. If the recommended adaptation measures are implemented, students in both countries will benefit from fewer climate-related learning interruptions and will have more conducive learning environments. Because these interventions would be in government schools, students who benefit will be from a broad cross-section of society, including lower-income groups.

Community-level perspectives were integrated throughout the project through interviews with principals, school administrators, parent committee members, and school management committee members. This community participation helps to create a sense of ownership, build community resilience, and promote long-term sustainability. The team recommended continuing community involvement initiatives already present in many schools, such as tree planting, beautification, and cleaning of the grounds. Parents and the community are also involved in school construction, and the project recommendation was to improve and enhance this partnership. Continued community engagement will enhance local knowledge of climate mitigation and adaptation and will leverage students, teachers and parents as change agents.

Environmental outcomes

Creating or enhancing outdoor cooling spaces by planting appropriate native tree species on school grounds was an important recommendation. Many school sites lack a sufficient number of trees to provide respite on hot days. The team also recommended that mature trees should be preserved when preparing a new school site or new school building location for construction. If followed, these recommendations are expected to result in increased carbon sequestration. Increased tree cover in schoolyards contributes to carbon capture, helping offset emissions and promoting sustainability.

Tree planting has numerous environmental co-benefits. Trees provide essential shade, which helps lower surface temperatures on school grounds, mitigating heat island effects. Tree-shaded areas can be significantly cooler and reduce heat gain in school buildings, creating a more comfortable environment for students and reducing the need for energy-intensive cooling systems in classrooms. Trees improve air quality by absorbing pollutants and filtering harmful particulates and help manage stormwater runoff by improving soil absorption and reducing erosion. Planting trees can create habitats for various species, promoting biodiversity and can also increase students' ecological awareness and foster a connection to nature.

Another key recommendation was to invest more in maintaining existing buildings. Continued investment in existing facilities reduces emissions associated with new construction and the manufacturing of construction materials and reduces waste generated when demolishing existing buildings. Buildings that are more resistant to natural hazard events experience less damage and resulting debris when such events occur.

Economic outcomes

The adaptation measures recommended in the diagnostics will lessen the damage to infrastructure and environment due to extreme weather and floods and subsequently decrease government expenditures, enhance learning days and therefore the productivity of schoolchildren and teachers (cognitive performance and more). More effective education systems generally lead to an increase in income, reduce morbidity and mortality due to health effects, and lower inequality and poverty.

TRANSFORMING AYODHYA'S WATER SUPPLY SYSTEM

Sector
Water

Resilience Phase
PREPARE RESPOND RECOVER **ADAPT**

Highlights
Community wellbeing · Ecological uplift · Carbon mitigation · Waste reduction · Accessibility · Healthcare · Safety

Project owner
Ayodhya Development Authority

Location
Thane, India

Communities impacted
Urban

Hazards mitigated
Water stress (urban focus)

Case study provided by:
Bentley

Number of people made more resilient
75,000

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RACE TO RESILIENCE

The Ayodhya water supply project aimed to convert the old, leaky pipelines into a robust 24x7 pressurised water supply, ensuring every home had access to clean water at a minimum pressure of 2.1 bar. The project used innovative variable frequency drive (VFD) pumps and Bentley System's WaterGEMS software to significantly improve residents' quality of life, reduce CO_2 emissions and save costs, setting a benchmark for sustainable water and wastewater infrastructure.

ABOUT THE PROJECT

In the bustling city of Ayodhya, India, a transformative project was set in motion to revitalise the ancient water supply system. To provide continuous drinking water to emerging economies throughout the country, the government of India implemented their Atal Mission for Rejuvenation and Urban Transformation (AMRUT) 2.0 programme in October 2021, mandating that all 3,000 utilities in 4,800 urban cities establish reliable, 24-hour water distribution and sewerage services accessible to all households.

In accordance with this initiative, Ayodhya Authority commissioned Geoinfo Services to engineer an urban pressurised water supply system, eliminating Ayodhya's existing gravity-fed distribution network. As one of India's most sacred and important pilgrimage sites where the floating population has reached 24.2 million, there is an urgent need for a sustainable solution to the water and wastewater treatment, distribution, conservation, and management.

The scope of the project required Geoinfo Services to renovate the city's intermittent, leaky, and ageing network, which generates a 50% non-revenue water (NRW) rate. They had to ensure the provision of safe and dependable drinking water through functional taps to all Ayodhya homes. A revered, ancient destination city visited by millions every year, Ayodhya's new water supply scheme will significantly

Real time flow delineation

impact society and the region, establishing 24-hour access to clean water, reducing waterborne illnesses, and boosting the urban economy.

Aligned with the government's AMRUT programme, Geoinfo Services needed to implement direct pumping and increase the residual nodal pressure of the Ayodhya water network. To avoid extensive energy consumption and cost, Geoinfo Services considered adopting variable frequency drive (VFD) pumps to accommodate the varying demands and pressures of Ayodhya's new pumped network more efficiently and economically during different periods throughout the year.

Given the lack of legacy information available for piped and pumped water distribution in the city, as well as the haphazard layout of the existing old pipelines, Geoinfo Services faced challenges modelling the large-scale network and digitally incorporating the new VFD technology into the hydraulic model. Realising that they needed a solution to model

the existing large-scale network with hundreds of pipes and nodes, as well as develop scenarios to incorporate multi-sourced data and the pressurised VFD technology, Geoinfo Services explored various software options. The solution would need to accommodate the extensive network size and voluminous associated data required to simulate and manage multiple digital distribution scenarios. To address these challenges, Geoinfo Services turned to Bentley Systems for use of their advanced hydraulic modelling and digital twin technology.

The project utilised Bentley System's WaterGEMS software to redesign the city's water supply system, reducing NRW and ensuring a pressurised water supply with a minimum of 2.1 bar pressure at all nodes. The software's GIS integration and hydraulic modelling capabilities allowed for efficient planning and design, contributing to the project's economic sustainability by saving energy and costs.

The introduction of VFD pumps, a groundbreaking technology in India, optimised energy consumption by adjusting pump speeds according to demand and pressure changes. This innovation, supported by WaterGEMS, is expected to save significant energy and costs for the country.

Furthermore, the project's digital twin, created using Bentley System's WaterSight software, provided a virtual representation of the water supply system, enhancing operational strategies and decision-making. This digital transformation allowed for real-time monitoring and predictive analysis, ensuring the system's resilience against unexpected events.

WaterSight

OpenFlows WaterSight by Bentley is a digital twin-based solution for real-time water supply and distribution management. It integrates SCADA, GIS, and hydraulic modelling for operational insights, proactive maintenance, and climate resilience, enhancing water system efficiency and reliability.

Among its key features, WaterSight bridges the gap between Operational Technology (OT) and Information Technology (IT), offering immersive visualisation, analytics, and a timeline of change for water systems. Its scalable environment ensures that the entire utility has access to essential performance data, fostering informed and confident decision-making.

WaterSight is a pivotal tool for achieving climate resilience in water systems. Proactive leak detection enables early intervention and reduces water loss; real-time modelling and analysis help maintain high water quality standards; and insights into pump and tank performance help improve energy efficiency, contributing to sustainable resource management. Moreover, current and forecasted performance of water networks support capital planning and ensure that investments are directed towards enhancing system resilience.

OUTCOMES

Social

The project brought significant social improvements to Ayodhya. It provided a reliable 24x7 water supply, reducing health expenses by 50% and saving families about $25 monthly. Women's time spent fetching water was reduced, allowing them to pursue income-generating activities. The project also eliminated water-related quarrels and improved the quality of life for the city's residents.

Environmental

Environmentally, the project led to a reduction of 347 tons of CO_2 emissions annually. It saved 1.35 hectares of land required for constructing service tanks and prevented water leakages, contributing to a healthier ecosystem. The project also anticipated risks such as epidemics and stampedes due to erratic water supply, which were mitigated by the new system.

Economic

Economically, the project achieved significant savings. It reduced energy costs by $46,025 per year for Ayodhya city and saved $5.45 million by avoiding land acquisition for new tanks. The decrease in NRW from 50% to 15% resulted in a daily saving of 11.95 million litres of water, translating to $1.09 million annually. Additionally, the project saved considerable time for land acquisition and reduced medical bills for families.

Leveraging Bentley’s technology saved 1,000 hours planning, designing, and implementing a cost-efficient water supply solution. WaterGEMS’ capability to model hundreds of assets saved $121.75 million in energy costs and the digital twin optimised pipeline diameters and network operations, saving $2.5 million in material costs and $1.5 million in annual system operating costs.


SOLUTIONS

APPLICATIONS FOR SATELLITE TECHNOLOGY

SHORT CASE STUDIES

Earth observation (EO) technology plays a vital role in climate-resilient infrastructure by offering high-resolution data through satellite imagery, aerial surveys, and remote sensing technologies. EO enables the monitoring of environmental conditions such as temperature, precipitation, and vegetation health, which are critical for understanding the impact of climate change. This data is collected using sensors that can capture images in different parts of the electromagnetic spectrum, from visible light to infrared, allowing for analysis of land, water, and atmosphere dynamics.

EO technology uses satellites such as the Sentinel-2, Landsat, and MODIS, which capture images of the Earth's surface at regular intervals. These satellites are equipped with instruments that record various environmental parameters. The images and data collected are processed using geospatial analysis tools that provide a clearer understanding of climate trends, drought patterns, vegetation health, and water levels. For example, Water Observations from Space (WOfS) and the Normalised Difference Vegetation Index (NDVI) can assess water bodies and vegetation health respectively.

One of the most valuable uses of EO is time-series analysis, which tracks changes in an environment over time. This enables governments, policymakers, and scientists to assess how climate-related phenomena like droughts, floods, and temperature extremes evolve. The processed data is then integrated into models that can simulate future scenarios, guiding more informed decision-making for infrastructure and environmental management.

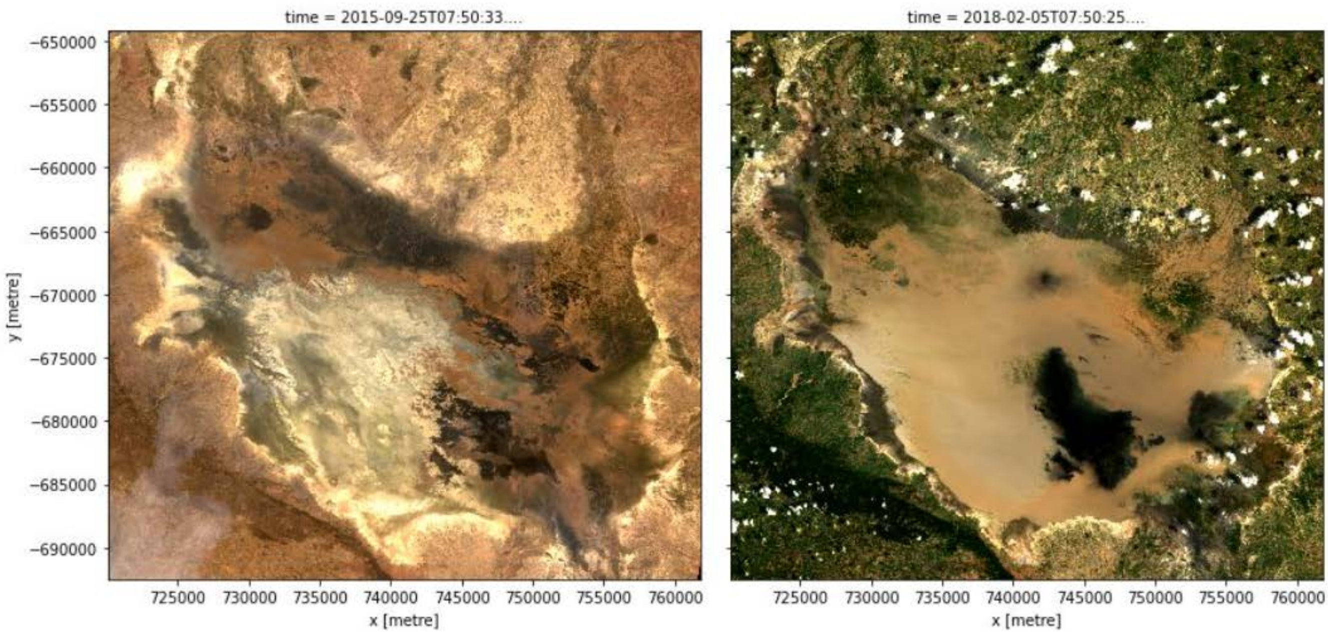
These technologies are increasingly used worldwide to support climate resilience efforts. As climate-related disasters become more frequent, integrating EO technology into national planning processes can help safeguard communities, economies, and ecosystems.

MONITORING LAKE SULUNGA'S WATER LEVELS IN TANZANIA

In Tanzania, EO technology has been employed to monitor the shrinking of Lake Sulunga (also known as Bahi Swamp), a critical water source for surrounding communities. Located in a semi-arid region, the lake is vulnerable to drought, threatening local livelihoods dependent on agriculture, livestock, and fishing. Using Digital Earth Africa's (DE Africa) satellite data, the National Bureau of Statistics (NBS) in Tanzania conducted time-series analyses of water extent in Lake Sulunga from 2013 to 2019, revealing significant fluctuations in water levels.

The data from DE Africa, accessed through the WOfS product, allowed the NBS to assess when the lake was at its lowest and highest levels. This EO analysis supports SDG 6.6.1, which aims to protect water-related ecosystems. By tracking these changes, policymakers can develop better water management strategies, ensuring the sustainability of Lake Sulunga for the surrounding communities in the face of recurrent droughts.

Minimum water observed in September 2015 and maximum water observed in February 2018



Global Partnership for Sustainable Development Data

Location
Tanzania

Authored by:
Digital Earth Africa

LEARN MORE

MAPPING URBAN HEAT ISLANDS IN THE UK

In the UK, EO technology is being used to monitor the impact of extreme heat waves, which are becoming more frequent due to climate change. In a project backed by the UK Space Agency, Ordnance Survey has been collaborating with the National Centre for Earth Observation (NCEO), to map urban heat islands (UHIs) — areas where dense infrastructure causes higher temperatures — using EO data. The project utilises satellite data from thermal infrared sensors to map land surface temperatures across the country.

The data enables local governments to identify areas at high risk of heat stress, particularly in densely populated cities. This information informs urban planning, such as identifying where to plant trees, create green spaces, or retrofit buildings with cooling technologies. By mitigating the UHI effect, the UK is better prepared to protect vulnerable populations, reduce energy costs, and prevent heat-related illnesses, contributing to its broader climate adaptation goals.

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Ordnance Survey

Location
UK

LEARN MORE

UNOSAT'S ROLE IN ENHANCING DISASTER RESPONSE CAPABILITIES

The UN Satellite Centre (UNOSAT), part of the UN Institute for Training and Research (UNITAR), provides satellite analysis, training and capacity development to support disaster management and humanitarian efforts globally. By providing timely satellite-derived data and analysis, UNOSAT significantly enhances countries' disaster response capabilities, enabling informed decision-making and efficient resource allocation during emergencies.

UNOSAT offers various services essential for disaster management, including rapid mapping. Rapid mapping allows for the quick production of satellite imagery and mapping products, crucial for understanding damage after a disaster and providing accurate damage assessments that can help governments and humanitarian organisations prioritise interventions based on the severity of the destruction. This capability is particularly important in post-disaster situations where swift decision-making is critical.

UNOSAT's impact can be seen in the response to the 2023 Türkiye-Syria earthquake. On Monday 6 February 2023, two major earthquakes struck Türkiye and the northwestern parts of Syria in the early hours of the day. The first, a magnitude 7.8 earthquake, struck west of Gaziantep at 1:17 am UTC. Just a few hours later, another strong earthquake of magnitude 7.5 struck the region at 10:24 am UTC, with its epicentre 100km north of the first one. These events caused catastrophic damage and triggered a full-scale humanitarian disaster, as the region was home to over 4 million vulnerable and displaced people who already depend on humanitarian assistance. Over 50,000 lives were lost and thousands of buildings collapsed and were destroyed.

The International Federation of Red Cross and Red Crescent Societies (IFRC) activated the UN Satellite Centre (UNOSAT)'s Emergency Mapping service over both Türkiye and Syria. UNOSAT triggered the International Charter: Space and Major Disasters to collect satellite images of Syria.

The UN and humanitarian agencies rapidly responded to the event. The International Charter Space and Major Disasters and the UNOSAT Emergency Mapping Service were activated to provide data-driven maps and products across the region.

Within hours, satellite imagery was processed to produce damage assessment maps, providing critical information about the extent of destruction and infrastructure damage. This rapid availability of information enabled stakeholders to identify priority regions for aid delivery and establish temporary shelters effectively. UNOSAT's response significantly improved coordination among agencies and optimised resource allocation in a difficult recovery environment, enhancing the overall effectiveness of humanitarian operations.

UNOSAT also assisted during the wildfires that devastated parts of Chile in early 2023. Extreme heat and prolonged drought led to significant destruction, burning over 400,000 hectares and forcing thousands to evacuate. In response, UNOSAT provided satellite imagery and analysis to support the Chilean government and local authorities. By utilising high-resolution satellite data, UNOSAT produced detailed maps showing the extent of the wildfires, enabling local authorities to visualise the spread of the fires and prioritise response efforts. UNOSAT's real-time data monitoring allowed for ongoing assessments of the wildfires' progression, providing essential situational awareness for emergency response teams. This information was critical for adapting strategies as conditions changed.

In addition to immediate support, UNOSAT works with local stakeholders to enhance their capacity to utilise satellite data for disaster management. Training sessions educate local authorities and NGOs on interpreting satellite imagery and integrating it into their response plans, fostering a culture of preparedness. This investment in local capacity ensures countries can independently leverage technology during emergencies, strengthening their resilience. Furthermore, UNOSAT makes satellite-derived data accessible, allowing countries to utilise these resources for disaster management planning and fostering collaboration among various stakeholders.

unitar United Nations Institute for Training and Research

UNOSAT United Nations Satellite Centre

Location
Global

LEARN MORE

ARCADIS FLOOD RISK CALCULATOR

The Flood Risk Calculator (FRC) is an innovative Python-based tool developed by Arcadis that builds on existing approaches to flood risk assessments while maintaining a higher degree of flexibility and granularity than most individual methodologies and tools can achieve on their own. The FRC draws on a variety of existing methodologies across the US, including FEMA's Hazus, Flood Assessment Structure Tool (FAST), and CBA Toolkit models, as well as the USACE's Generation II Coastal Risk Model (G2CRM) and Hydrologic Engineering Center Flood Damage Reduction Analysis (HEC-FDA) model.

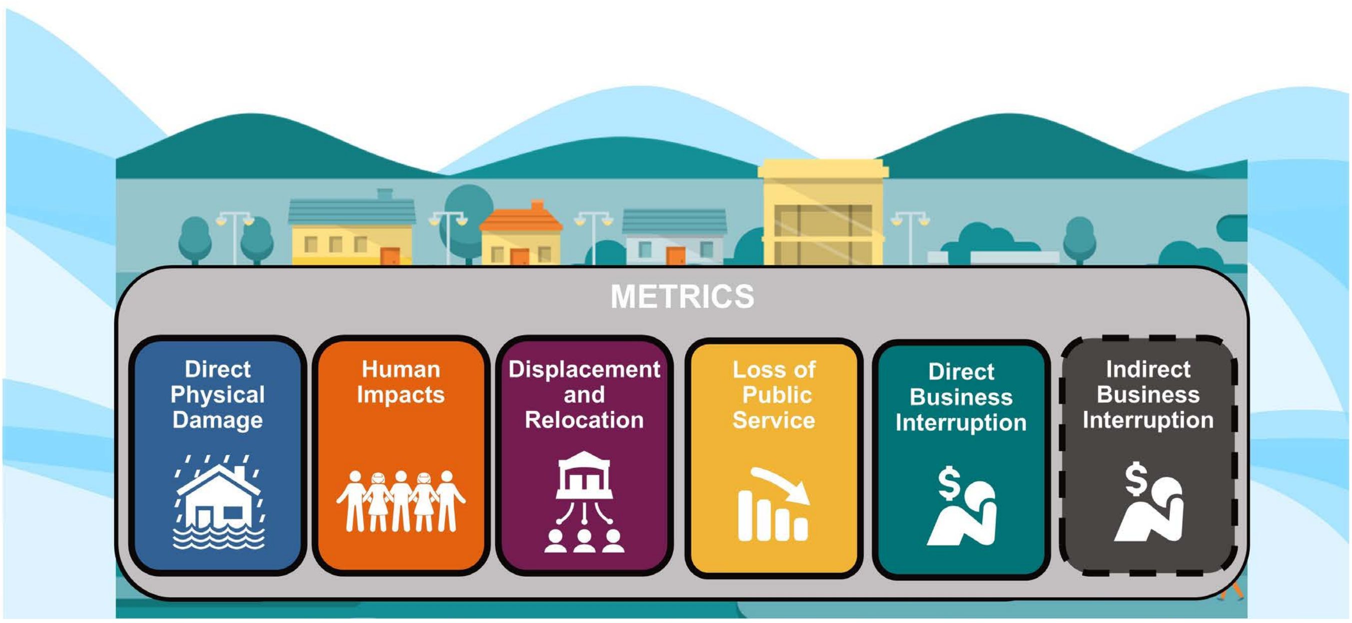
The FRC combines GIS and tabular data using Python scripts to quantify and evaluate site-specific and collective impacts of individual flood events, bigger-picture sea level rise impacts, annualised flood risk, and present value risk within project areas ranging from small neighbourhoods to large metropolitan regions.

The FRC offers enhanced computational capacity and automation, enabling efficient evaluation of large-scale projects across numerous flood events and project alternatives. It assesses flood impacts by analysing asset-by-asset exposure, vulnerability, consequence, and overall risk, applying industry-standard depth-damage functions associated with various asset types and a range of different flood events with varying probabilities to arrive at probability estimates, or expected annual damages.

The FRC is capable of estimating flood-related impacts at the building scale across a handful of different metrics, including direct physical damages to buildings and their contents; human impacts including shelter needs, impacts on mental stress and lost productivity, residential displacement, and temporary business relocation costs, and the disproportionate impacts of physical damages on lower-income residents; impacts of loss of service for certain public assets such as fire stations and hospitals; and direct business interruption in terms of lost economic output, in addition to the generation of inputs needed to model indirect economic impacts using an external programme called IMPLAN.

Tailored for practitioners who work with local, regional, or state agencies, the FRC empowers decision-makers to compare and prioritise flood resilience alternatives and investments, substantiate the benefits of proposed projects and communicate those benefits effectively, and gain and retain community buy-in for proposed capital projects. In the last five years, Arcadis

Metrics on the Flood Risk Calculator



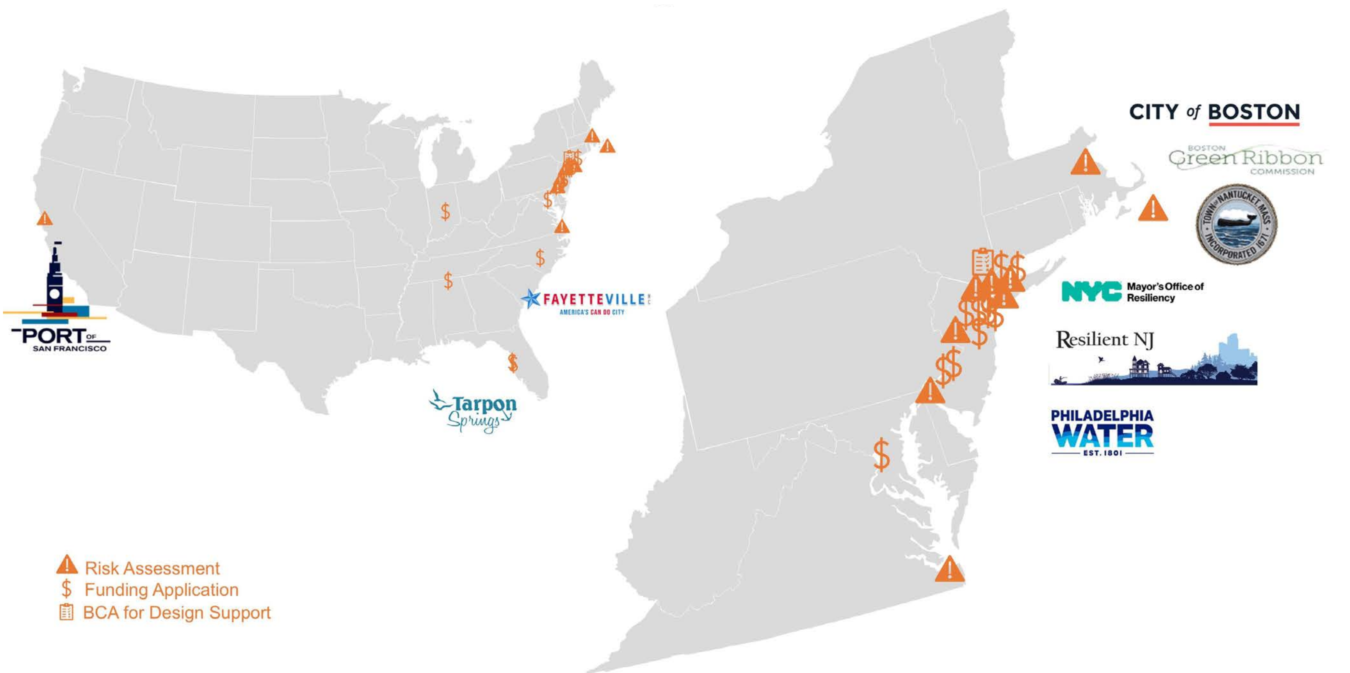
has used this tool on over 30 projects across 12 US states, from performing CBAs for successful federal grant applications to supporting local- and regional-scale climate adaptation planning. The FRC has helped quantify billions of dollars in avoided losses, supporting key climate adaptation projects and policy objectives across the US.

The FRC can play a major role in mitigating human impacts from flood events. By analysing exposure, vulnerability, and consequences, planners and responders can better understand the social implications of flood-related damages. The tool helps inform decision-makers in building more resilient, equitable communities. The tool also helps highlight the disproportionate impacts of floods on lower-income communities, ensuring that resilience investments consider social equity and protect vulnerable populations.

By evaluating flood risk and resilience projects, the FRC promotes the implementation of flood mitigation measures that minimise long-term environmental impacts. These projects often include nature-based solutions that reduce flood risks while restoring ecosystems and improving biodiversity.
The tool's capacity to assess the cumulative impacts of sea-level rise and flood events allows for the planning of sustainable, climate-adaptive infrastructure, reducing damage to the built and natural environment.

The FRC can also be used as a tool to quantify the economic benefits of flood resilience projects, supporting decision-makers in making cost-effective investments. Through its assessment of direct physical damages, business interruptions, and public asset disruptions, the tool aids in avoiding billions in potential losses. It also provides crucial inputs for CBAs, increasing the success of federal grant applications. By substantiating the long-term financial benefits of flood mitigation projects, the FRC supports sustainable economic growth and resilience.

Recent Risk Assessment using the Flood Risk Calculator



IFC BUILDING RESILIENCE INDEX

Sector

Construction

Finance

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Collaboration Safety

Project owner
International Finance Corporation

Project start/completion
Nov 2023 – Sep 2024 (RHDHV Assignment)

Location
Vietnam, Global

Communities impacted
Coastal, urban

Hazards mitigated
Tornados, cyclones, hurricanes, typhoons, flooding, storm surge, tsunami, fire, subsidence, landslide, volcano, earthquake

Case study provided by:

Royal HaskoningDHV Enhancing Society Together

Building Resilience Index

LEARN MORE

The Building Resilience Index (BRI) is an innovative web-based tool developed by the International Finance Corporation (IFC), part of the World Bank Group. It provides a comprehensive hazard mapping and resilience assessment framework tailored for the building sector.

ABOUT THE PROJECT

The BRI supports the development of safer urban environments by promoting the construction of resilient buildings that protect occupants during extreme weather events and climate-induced disasters. The BRI enables stakeholders such as developers, insurers, and governments to evaluate and enhance building resilience against climate risks, ensuring transparency and facilitating risk mitigation across the sector. Royal HaskoningDHV was assigned by IFC to implement a pilot project in Vietnam, applying the BRI approach for five projects and providing recommendations to help improve the use of the BRI tool.

The BRI was created to address the increasing vulnerability of buildings worldwide due to the growing intensity and frequency of disasters, exacerbated by climate change. The platform offers location-specific hazard data and resilience measures, helping building owners and developers identify, manage, and disclose risks related to four primary hazard categories: wind, water, fire, and geoseismic activity. This empowers them to make informed decisions, fostering a culture of safety and resilience in communities.

BRI enables the integration of hazard mapping, risk assessment, and resilience rating in a user-friendly platform. By utilising BRI, stakeholders can evaluate the resilience of buildings during the design, construction, and retrofitting phases. The tool's web-based interface allows developers to input building specifications and receive a comprehensive resilience assessment, including a letter-grade rating that communicates risk levels clearly and enhances

communication between developers, insurers, banks, and regulatory bodies. The tool promotes transparency and encourages data reliability and accessibility for all parties, which is crucial for decision-making and financial assessment.

For operational continuity, the BRI suggests measures to ensure buildings can maintain power, water, and telecommunications access during and after hazard events. By applying these technologies, the BRI enhances the ability of developers and stakeholders to implement effective resilience strategies, ensuring long-term sustainability and safety.

The tool also encourages the adoption of best practices that minimise environmental impacts and enhance adaptive capacity. For instance, the BRI includes strategies to prevent urban flooding by ensuring that buildings do not exacerbate pressure on drainage systems. This proactive approach not only mitigates the environmental impact of construction projects but also supports broader urban resilience goals.

One notable example of the BRI in practice is its pilot implementation in Vietnam, a country prone to typhoons, earthquakes, and flooding.

Royal HaskoningDHV has applied the BRI approach to five project sites in Vietnam to test this tool and undertake a climate resilience assessment. The selected projects include seaport buildings and infrastructure, educational, commercial, residential, and industrial sites, which were assessed against wind, flood, fire, and geoseismic hazards. These applications support IFC to update the BRI tool based on useability, resilience measures, and proposed adaptation solutions.

The BRI provides significant economic benefits by reducing the costs associated with disasters. By promoting resilient construction practices, it helps minimise damage and operational disruptions, leading to lower insurance premiums and fewer post-disaster recovery costs. The tool also facilitates financial institutions and insurers in accurately assessing risk, which can lead to better pricing for resilient buildings and reduce long-term financial liabilities for building owners.

DRONES AND REMOTE SENSING FOR RAIL ASSET MANAGEMENT

Sector

Transport

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Safety

Project owners

Network Rail, Islamic Republic of Iran Railways

Location

Global, UK and Iran

Communities impacted

Urban, rural, and coastal

Hazards mitigated

Water stress, coastal flooding, other coastal events, oceanic events, hurricanes/cyclones, extreme wind, extreme heat

Case study provided by:

INTERNATIONAL UNION OF RAILWAYS

LEARN MORE

Drone technology plays a pivotal role in enhancing the safety and efficiency of rail networks, especially during extreme weather conditions. Railway providers in the UK and in Iran are using different drone-mounted sensors to monitor hard-to-reach and hazardous areas. These drones provide real-time, up-to-date information, enabling quicker detection of potential defects such as buckled rails or obstructions caused by storms or heatwaves.

ABOUT THE PROJECT

With the rapid development of drone technology that has a higher range of autonomy and more advanced equipment, drones are now being used for a wide range of applications in railways including remote monitoring of rail networks during extreme weather events. Drones now carry high-end camera equipment or thermographic cameras, but also sensors and measurement equipment and can withstand a range of weather conditions, including wind, low temperatures and moderate rain or snow.

Currently, rail inspection tasks often involve the use of dedicated vehicles or converted road vehicles that require a railway track to operate, sometimes diminishing the capacity of the line. In other cases, it is necessary for personnel to be inside the rail corridor to perform visual inspections or to perform inspections in hard-to-reach areas, increasing the risk of accidents. Monitoring of rail assets is particularly difficult in such a linear network infrastructure and especially in extreme weather conditions.

The use of drones for railway inspections can greatly enhance safety in several ways, allowing infrastructure managers to have up-to-date information on the condition of the railway's lines.

The Uncrewed Aerial Systems (UAS) has the advantage of being airborne, and by utilising Global Navigation Satellite Systems, it can fly above the railway track

RailwaySmart Crisis Management Robotic Drone. © Islamic Republic of Iran Railways

to capture observational data. Employing different drone-mounted sensors, detecting potentially dangerous defects and obstructions during extreme weather events such as storms and heat waves has become quicker and safer.

During heat waves, which are becoming more frequent in many parts of the world that previously were not used to prolonged high temperatures, tracks are known to expand and therefore are at greater risk of buckling. Buckled rails bring a risk of derailment, therefore speed restrictions or track closures are often imposed during extreme heatwaves.

UK Railway Infrastructure Manager, Network Rail, is testing the use of drone inspection to measure critical rail temperature. Drone-mounted thermographic cameras are being tested with the hope that they can be used for accurate and instant information on track temperatures and therefore help detect issues and manage railways in a smarter and safer way. Additionally, Network Rail is using UAVs to increase situational awareness for control teams and engineers in the case of failures, such as flooding, embankment and cutting failures.

Elsewhere, the crisis management department of the Islamic Republic of Iran Railways is also employing UAVs to build resilience in its network. Using an autonomous drone, equipped with AI algorithms, they can detect numerous hazards and help incident prevention and warnings. Equipped with chemical, smoke and gas sensors, as well as high-definition cameras and microphones, the drone can assess damage and issue alerts to the crisis management team. Receiving real-time emergency data (e.g. weather alerts and seismic activity), the drone enables real-time monitoring and data collection, including train traffic data to identify hazards. Obstructions such as animals, floods, and landslips have been detected and warning is immediately transferred to train drivers.

The essential benefit of this technology is safety. Landslips and trees or broken rails can cause derailments and be a serious risk to life. Early detection of these hazards means a safer railway for the travelling public, lineside neighbours and workforce. Before the use of these drones, a team of maintenance workers would have to access the site directly for inspection, the drone technology allows for a reduction in the exposure to the risks associated with working lineside. The use of drones and remote sensing also prevents animal collisions and mortality, as warning sounds can be given to deter animals from crossing tracks ahead of trains. Additionally, the technology can quickly detect spills to alert maintenance and clean-up teams much faster than usual, allowing for the damages to be minimised.

It is essential for society that the railways continue to run and are back in normal running order as quickly as possible after extreme weather events. This technology helps make railways more punctual and reliable so that people can rely on this sustainable mode of transport. Moreover, the increase in infrastructure reliability and the punctuality of service contribute to economic growth, and the project also allows for more efficient allocation of resources in track maintenance.

ENHANCING FLOOD RESILIENCE: PREDICTIVE TOOLS FOR FLOOD AND FLASH FLOOD NOWCASTING

Sector

Water

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Safety

Project start/completion

June 2022 – June 2025

Location

Tennessee Valley, US

Communities impacted

Urban, Rural

Hazards mitigated

Flooding

Case study provided by:

LEARN MORE

Floods and flash floods cause significant economic damage and fatalities worldwide. A study conducted by Northeastern University highlights the development of hybrid physics-AI precipitation forecasting tools, which outperform traditional weather prediction models. These emerging tools are being evaluated in the Tennessee Valley and hold potential for global adaptation, enhancing flood preparedness and resilience.

ABOUT THE PROJECT

Floods and flash floods cause significant economic damage and fatalities worldwide. A study conducted by Northeastern University highlights the development of hybrid physics-AI precipitation forecasting tools, which outperform traditional weather prediction models. These emerging tools are being evaluated in the Tennessee Valley and hold potential for global adaptation, enhancing flood preparedness and resilience.

Floods and flash floods cause the most economic damage among all natural hazards in developed nations and result in the most lives lost in developing nations. In 2023, natural disasters caused 86,473 fatalities, impacted 93.1 million people, and resulted in $202.7 billion in economic losses as reported by the UN and CRED. Floods and flash floods continue to contribute substantially to these figures, underscoring their severe global impact. Although floods may be triggered by extreme rainfall, causality depends on factors such as soil moisture, soil type, and topography, making predictive understanding more challenging. Specifically, flash floods are often caused by a combination of heavy and convective rainfall, which tends to overwhelm river management centres and water resources operations.

One important step for flood resilience and adaptation is developing predictive tools for nowcasting, which

The Tennessee Valley is the drainage basin of the Tennessee River It stretches from southwest Kentucky to north Alabama and from northeast Mississippi to the mountains of Virginia and North Carolina.

refers to short-term precipitation forecasting (0-6 hrs lead time). Traditional forecasting methods like persistence, radar echo advection, Numerical Weather Prediction (NWP), Cloud Resolving Models (CRM), and data-driven extrapolation often face challenges in accurately predicting extreme precipitation events.

However, recent advancements in machine learning, such as Google DeepMind's physics-free Deep Generative Model of Rainfall (DGMR) or physics-embedded DGMs like NowcastNet, have shown promising advancements in this field. Results from a case study conducted by Northeastern University in the Tennessee Valley Authority (TVA) region, which manages the Tennessee River system, have shown that hybrid physics-Al methods, such as NowcastNet, can outperform the widely used numerical weather prediction models in the US.

Insights from this study are helping the TVA to complete its mission of managing flooding emergencies and hydropower operations in the Tennessee Valley and beyond. They will be using the hybrid physics AI-based model as a test case to generate high temporal resolution forecasts for convective precipitation. This work is jointly co-evaluated with Machine Learning developers, hydrologists, water resources engineers and scientists, as well as river managers and hydrometeorologists.

Once these tools are evaluated in the context of developed nations such as the US, they can be adapted for use in developing nations. For example, the Damodar Valley Corporation (DVC) in West Bengal was inspired by and modelled after the TVA; implementing advanced hydrological forecasting methods at DVC could significantly enhance flood management and optimise water resources in the region. Extending that inspiration, the methods and tools now developed can be adapted to India. Additionally, similar strategies could benefit other flood-prone areas, such as the Citarum River in Indonesia, the Rufiji district in Tanzania, and the Surma-Meghna basins in Bangladesh.

This approach can provide critical insights and enhance early warning systems, enabling better preparedness and response to flash floods. By leveraging the capabilities of both radar and satellite imagery, it is possible to extend the benefits of advanced nowcasting techniques to a wider array of environments, ultimately contributing to more resilient flood management strategies worldwide.

FIELDSIGHT: AN OPEN-SOURCE REMOTE MONITORING SYSTEM

Sector

Construction Water Education

Transport Built Environment

Resilience Phase

PREPARE RESPOND **RECOVER** ADAPT

Highlights

Inclusivity Collaboration Safety

Community engagement Capacity building

Disaster management

Project owners
UNOPS, Miyamoto International, Nepal Innovation Lab, World Vision, Harvard Innovation Lab, Kobo Toolbox

Project start/completion
2016 – ongoing

Location
Nepal

Communities impacted
Rural

Hazards mitigated
Hurricanes/cyclones, earthquakes

Case study provided by:

FieldSight, an open-source remote monitoring system was developed by UNOPS, INGO (World Vision), Miyamoto International, the Government of Nepal, and others to solve the critical problem of effective and efficient rebuilding after the devastating 2015 earthquake in Nepal. Miyamoto used FieldSight mobile data collection and web technology to enhance humanitarian and development projects in Nepal, monitoring and ensuring construction quality assurance on over 30,000 houses, 300 Water Sanitation and Health (WASH) facilities, 35 schools, 50 police stations, and 100 km of roads.

ABOUT THE PROJECT

FieldSight has been used in 16 countries for multiple types of data collection and assessments. Outside Nepal, the platform is being used to monitor the installation of 2,200 solar facilities in Pakistan, conduct building inspections for cyclone resilience in Tonga, HSSE monitoring in Myanmar, monitor road construction in Haiti, and oversee the construction of public buildings in Ukraine.

Low-quality infrastructure can introduce significant health and safety issues; network failures and infrastructure collapses can lead to widespread destruction and death. In Nepal, more than 7,000 schools and 800,000 houses collapsed after the devastating 2015 Gorkha earthquakes. Post-disaster analyses revealed key weaknesses in oversight and construction that led to the lack of inclusion of seismic resistance, even where designs and local buildings called for it.

Number of people made more resilient ~150,000

FieldSight empowers humanitarian and development agencies to collect more usable and actionable data to help populations directly affected by rapid and slow-onset disasters. With the increasing frequency and magnitude of extreme climatic events, vulnerable pockets in remote areas are the most impacted group. Integrating community-based field data collectors, such as local contractors and engineers, into the data collection process ensures that local insights are captured, thereby enhancing community involvement and empowerment.

FieldSight is the first tool of its kind to use mobile and web technology for quality assurance and monitoring of infrastructure projects. The FieldSight mobile app connects people and organisations working in remote field locations with engineers, designers, government agencies, and donors who can help provide guidance and oversight to help meet quality standards. Field teams who are embedded in local communities can collect data, receive advice, and contribute to a process that helps review, assess, analyse, and act on that data for the betterment of local infrastructure. In essence, FieldSight closes the loop to ensure that resilient designs become resilient communities. It is a real-time data collection system that enhances the quality of data collected and enables real-time analysis and response throughout the infrastructure lifecycle. It improves the efficiency of decision-making in the infrastructure sector by enabling more efficient data collection.

Miyamoto's post-disaster assessments in Nepal found flaws in management and construction, leading to a failure to include seismic resilience in designs and local buildings. Low capacity among local contractors and engineers makes it difficult to construct higher-quality and advanced infrastructure and conduct oversight. FieldSight aims to improve capacity-building among local populations to inform resilient construction methods and enforce quality assurance inspection, potentially preventing tragedies and contributing to more equitable societies. By addressing these issues, it aims to improve the quality of data collected and facilitate more effective infrastructure management.

FieldSight consists of mobile and web apps that create a closed-loop data collection and management system that helps to ensure that stakeholder perspectives are included in projects. This is especially important for stakeholders in the field whose voices can be misrepresented when data collection processes are not implemented well by headquarter-level offices.

The mobile app is designed to support and enhance the work of those managing and monitoring projects in the field. They can use the mobile app to record information about the status and progress of infrastructure projects, access key information about the project and quality standards, and communicate with project managers. The web app allows technical and management staff to review data from the field, communicate with field staff, and explore and analyse data at the site, regional, project, and organisational levels. Enhanced community involvement also contributes to improved transparency and accountability, in turn attracting more investment through increased investor confidence, fostering economic growth and development.

FieldSight leverages the advantages of existing humanitarian project monitoring methods bycoordinating them into an intuitive platform to help projects reach their full potential. Until now, monitoring and quality assurance of infrastructure projects have suffered from overreliance onqualified engineers and inefficient dispersed documentation techniques. Most oversight protocols include a trained engineer to provide regular oversight and guidance on-site. Unfortunately, there is a shortage of trained engineers in many developing countries, especially in remote locations, so supervision is often carried out by junior engineers, contractors, or community members without the requisite skills and knowledge. FieldSight facilitates capacity building by providing training and resources to local stakeholders, thereby enhancing the skills and capabilities of local contractors and engineers. This, in turn, fosters economic empowerment and increases employability, leading to a more skilled workforce.

Most monitoring processes are documented on paper or via multiple third-party mobile applications such as WhatsApp. This is a cheaper method upfront but

occupies a great deal of time when the data needs to be organised and digitised for analysis. Moreover, it is impossible to identify key issues from individual sites and see patterns of challenges that affect multiple sites. FieldSight offers offline data collection and secure data uploading for the infrastructure sector that has previously been unavailable. Kobo Toolbox survey software is also built into the platform so that surveyors can digitise many types of data from the field, including photos and signatures. FieldSight enhances this technology by automatically organising raw survey data into an easy-to-use platform where it can be contextualised for analysis and reporting. The mobile application includes features that help ensure high-quality work, including offline educational materials, timestamps and geotags on all data submissions.

Continuous monitoring can also help assess the environmental impacts of projects and mitigate potential negative effects before they cause significant damage. By facilitating precise project monitoring and quality control, FieldSight helps ensure that construction materials are used efficiently, reducing waste and minimising the environmental footprint of infrastructure projects. It promotes sustainable construction practices by providing guidance and oversight in real-time, thus encouraging the use of eco-friendly materials and techniques. FieldSight's user-friendly interface and real-time data-sharing capabilities help educate communities about environmental issues and the importance of sustainable practices, fostering a culture of environmental stewardship. With the integration of advanced technologies like AI and predictive modelling, the long-term environmental benefits are expected to be even more significant.

As FieldSight scales, it is planned to develop as an infrastructure asset management platform that enables analysis by climate and population change to help field staff improve responsiveness to the needs of communities. Infrastructure status and management data collected via FieldSight throughout an asset's lifecycle will be used to analyse the ways population and climate affect asset performance.

This data will contribute to an AI predictive model for asset performance that governments can use to better inform planning and decision-making. This will help make issues faced by communities more visible than ever.

These initiatives are focused on helping governments improve infrastructure planning and delivery. The Capacity Assessment Test for Infrastructure (CAT-I) assesses factors related to government capacity to target institutional and policy improvements. The Evidence Based Infrastructure (EBI) Initiative developed a framework for integrating existing datasets across all aspects of an asset's lifecycle. FieldSight integrates and builds on these initiatives ensuring data collection contributes to management needs.

Importantly, FieldSight drives positive economic outcomes by enhancing infrastructure quality and efficiency. By improving construction practices and monitoring, FieldSight reduces the need for frequent repairs and maintenance, leading to cost savings and increased efficiency. This not only lowers long-term maintenance costs but also optimises resource use, contributing to economic sustainability.

LIVE FLOOD INTELLIGENCE FOR REAL-TIME TRAFFIC ROUTING

FloodMapp's products ForeCast, NowCast and PostCast are designed to support the emergency response before, during and after a flood event by providing street-level, property-specific flood intelligence at a national scale. This intelligence allows emergency managers to take targeted action to coordinate evacuations, prevent damage to assets, re-route traffic, and deploy recovery resources and funding effectively.

Norfolk, Virginia, is particularly vulnerable to flooding due to its low-lying coastal geography and proximity to the Chesapeake Bay and the Atlantic Ocean. The city frequently experiences tidal flooding, heavy rainfall, and storm surges, exacerbated by climate change and sea-level rise. According to the City of Norfolk's resilience plan, the region is projected to see increased flooding events, necessitating innovative solutions for effective emergency response and community safety.

The City of Norfolk had access to a lot of information including flood sensors, and static flood studies. However, given the speed and scale of unfolding flood events, little actionable intelligence was available. Any solution to this problem had to be timely, accurate, and targeted. The City sought help from RISE Resilience Innovations, a Norfolk-based nonprofit that accelerates innovation and business growth around solutions to coastal communities' critical resilience challenges. RISE put out a global call with their Urban Mobility Resilience Challenge, seeking real-time flood modelling technology which can be used to help traffic navigate around flooded roads.

FloodMapp was selected for this challenge and worked with the City of Norfolk to understand their detailed use case requirements to work towards a solution.

FloodMapp received funding, business mentorship and access to the living laboratory of Coastal Virginia, to develop and validate its novel solution.

Leveraging the power of NowCast's real-time capability, FloodMapp was able to identify and access the data needed to meet the speed, accuracy, and granularity required. NowCast was implemented to run and refresh results every 15 minutes as new tidal and rainfall observations are ingested, producing one-meter resolution flood inundation models, accurate within inches.

City road data was used in RoadSafe, a powerful analytics service which predicts flooded roads based on NowCast inundation data. Flood depth thresholds, developed in collaboration with the city, were used to define road hazards and road closures respectively based on the depth of flooding over each road segment. The solution was then delivered to Norfolk's Department of Emergency Management, where they can view live road closures and road hazard segments which update dynamically as a flood unfolds.

FloodMapp, NowCast and RoadSafe flood intelligence are delivered and rendered as a city-wide common operating picture and single source of truth. This provides the City of Norfolk staff and Emergency Operations Centre (EOC) with hyper-local flood intelligence in real-time. This vital situational awareness has helped to inform emergency managers and public works officials in their operational response to flooding, which supports delivering community messaging, planning, and response decision-making.

FloodMapp's groundbreaking forecast technology mixes tidal, riverine and rainfall data to create a rapid, real-time flood inundation model. The information is automatically layered with Norfolk's citywide road

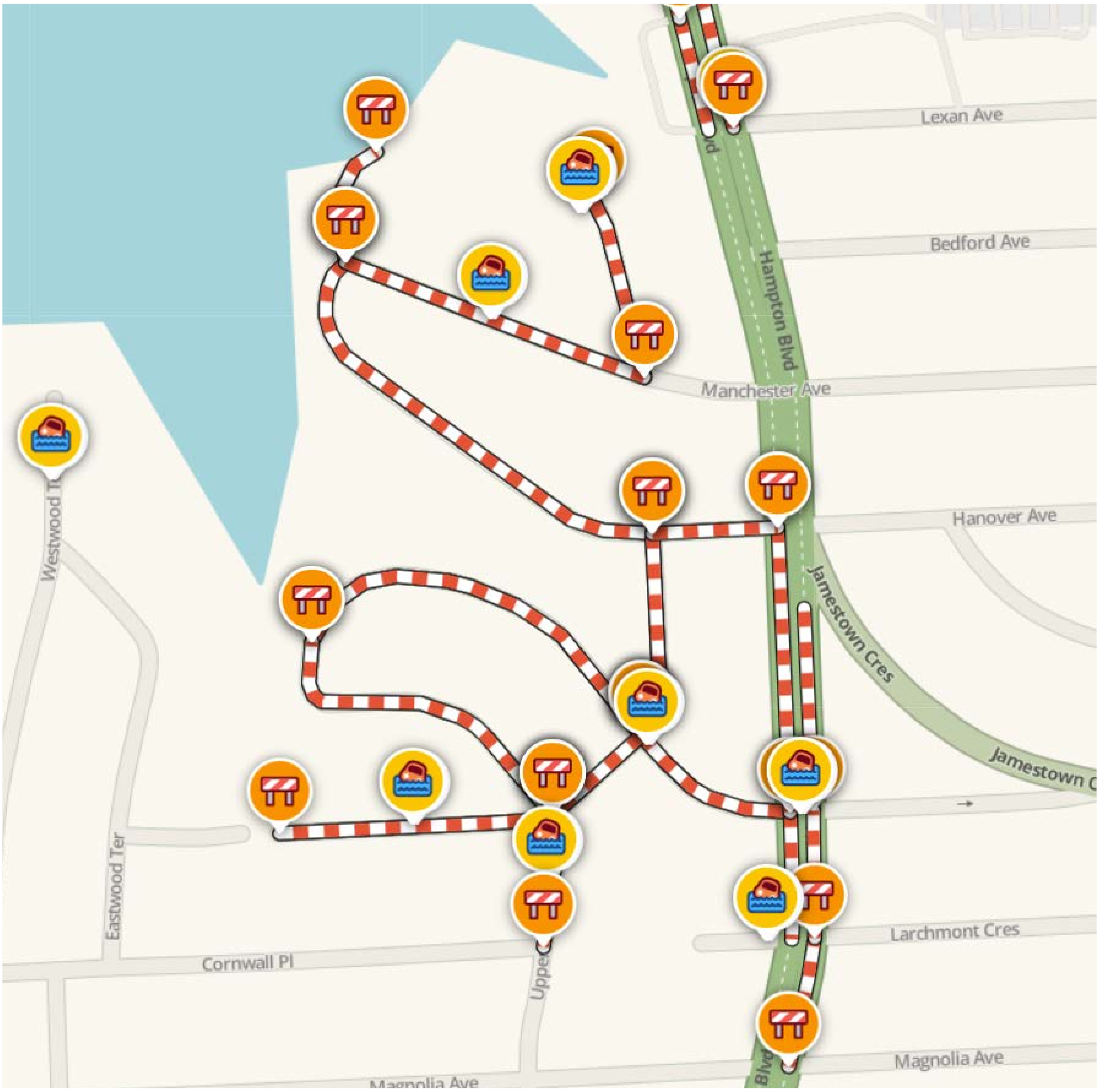
FloodMapp a safer future | The City of Norfolk | Resilient Norfolk Coastal Storm Risk Management | RISE Resilience Innovations

Location
Norfolk, Virginia, USA

LEARN MORE

network in a GIS and sent to Waze in real-time. Drivers using Waze receive pop-up icons and audio alerts to warn them about flooded streets along their route and help them avoid property and life-threatening hazards. Drivers can confirm flooding in the app, which helps validate FloodMapp's technology and makes future Waze alerts more accurate.

Since launching the system live to residents in October 2021, Waze users confirmed more than 4,348 flooded roads predicted by Flood Mapp RoadSafe. Drivers have provided over 9,452 thumbs-ups to validate these predictions (an average of 2.2 and a maximum of 72 confirmations per hazard).



Drivers using Waze receive pop-up icons and audio alerts to warn them about flooded streets along their route.

SURFACE WATER ASSESSOR TOOL

Sector

Water

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Safety | Property Protection | Collaboration

Project owner

Stantec

Project start/completion

May 2022 – Dec 2024

Location

Bedfordshire and Hertfordshire, UK

Communities impacted

Rural, Urban

Hazards mitigated

Flooding

Case study provided by:

Stantec, ResilienTogether, Central Bedfordshire, Hertfordshire, Department for Environment Food & Rural Affairs, Environment Agency

Flood and coastal resilience innovation programme

Part of the £200m Flood and coastal innovation programmes

LEARN MORE

The Surface Water Assessor is an innovative, digital floodwater management tool developed by Stantec which is supporting local authorities in Central Bedfordshire and Hertfordshire to make decisions around flood risks. The tool draws on data from a variety of sources including address point data, LiDAR digital terrain models, open street mapping, Ordnance Survey MasterMaps, road centerline data, sewer network data, and watercourse data.

ABOUT THE PROJECT

The Surface Water Assessor helps determine the potential for retrofit opportunities using sustainable drainage systems (SuDS) by producing visual GIS outputs and Excel calculations. This digital approach enables the automated identification of opportunities and the ability to improve outputs through user specifications. It is an exploration into the possibility that a technology-led approach could be used to manage flood risk. The outputs from this tool provide both a qualitative and quantitative assessment of a region, such as the locations and types of opportunities, the impermeable area it may be able to drain, flow paths and their elevation profiles, and overall cost.

Pix Brook, a stream which runs through Letchworth, Stotfold, and Arlesey, has a longstanding history of flooding. Central Bedfordshire Council (CBC) and Hertfordshire County Council (HCC) are working together to help mitigate flooding in the Pix Brook catchment area and under the Flood and Coastal Innovation Programme have received funding to pilot new approaches to decision-making. Both local authorities were keen to explore whether a technology-led approach could be used to help better understand the opportunities for small-scale interventions that could alleviate flood risk. As such, Stantec was appointed to support the councils with the project.

Working alongside partners, CBC and HCC secured funding from the Department for Environment Food and Rural Affairs (Defra) through the flood and coastal resilience innovation programme, now known as ResilienTogether. This funding enables the project to explore how data and digital-led approaches can help authorities better understand, manage and monitor the risks posed by flooding and to design appropriate, 'smart' interventions.

The Surface Water Assessor Tool evaluates each property or land parcel within a catchment area and outputs a full breakdown of opportunities, quantities, and costs, alongside a calculation of the impermeable area upstream that can be intercepted. This maximises the value for money of flooding resilience measures. In this case, Stantec looked at more than 200,000 land parcels and, using ten baseline datasets and information around local surface and foul water networks, determined the most appropriate location and type of SuDS intervention through the Surface Water Assessor tool.

Together, the group has identified a number of opportunities for further development in areas where solutions could be sited, based on a technical assessment, to help better understand and manage flood risks. For the Pix Brook project, they targeted numerous locations where a range of SuDS and natural flood management solutions could be deployed. This allowed for a more strategic approach and for feasibility assessments to be undertaken. The project also allows flood risk to be foreseen and managed and for interventions to be put in place to build resilience, avoiding damage to property and infrastructure and associated financial losses.

From a social standpoint, the project helps to improve safety and security and reduces the risk of damage and loss of life and property from flooding. Additionally, a developed understanding of local flood risks and appropriate mitigation strategies builds climate resilience for communities and provides reassurance to local residents. Outputs from the Surface Water Assessor Tool also assist with water quality issues and improve understanding about how and when flooding is likely to occur and the best way to support habitats while mitigating flood risk.

UHEAT: ASSESSING THE URBAN HEAT ISLAND EFFECT

Sector

Built Environment

Resilience Phase

PREPARE RESPOND RECOVER **ADAPT**

Highlights

Biodiversity
Carbon mitigation
Collaboration
Community wellbeing

Project owners
Arup, UCL Institute for Risk and Disaster Reduction

Location
United Kingdom

Communities impacted
Urban

Hazards mitigated
Heat stress

Case study provided by:

ARUP

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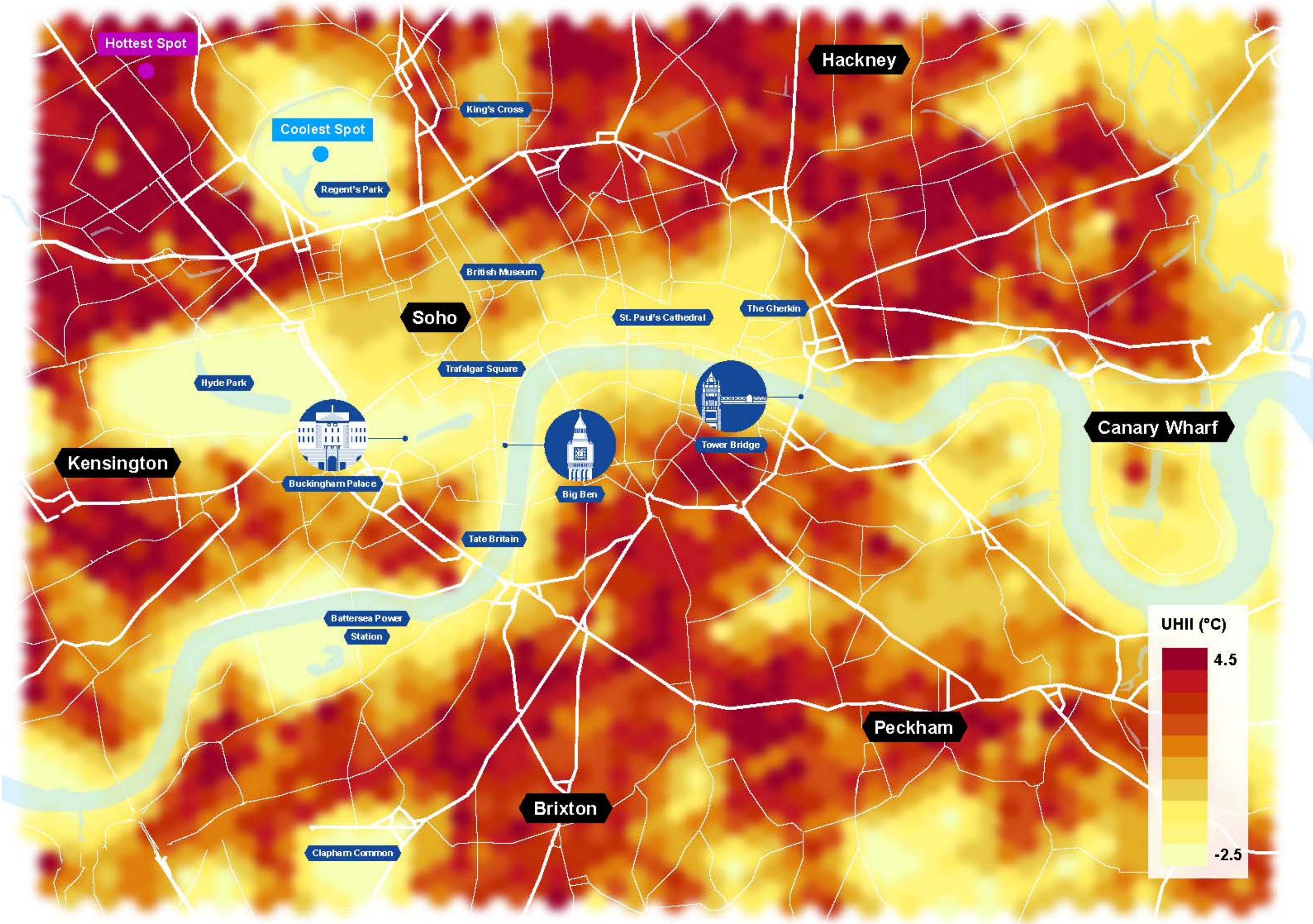
UHeat, a digital solution from Arup, uses a combination of satellite imagery and open-source climate data to analyse urban heat island (UHI) effects across huge areas of cities. It's able to identify the particular buildings, structures and materials that are causing temperatures to rise and translate this analysis into planning solutions.

ABOUT THE PROJECT

The impact of heat on our cities is becoming more profound. Urban environments are dominated by concrete buildings, tarmacked roads, steel and glass structures, and traffic congestion, all of which trap and amplify heat, creating UHIs. UHI is the phenomenon whereby urban areas experience higher temperatures than their rural surroundings. Globally, urban areas are growing, and UHI has many adverse consequences, such as increased pollutants and energy consumption, reduced water quality and compromised human health. As climate change brings more frequent and intense heatwaves, the UHI effect is exacerbated, putting immense strain on infrastructure.

Designing to mitigate UHI is difficult because there is no standardised and effective way to measure urban heat. Urban heat is frequently assessed using the thermal bands of sensors, however, these studies are limited to a snapshot of temperature at the time of image capture. Furthermore, they only provide land surface temperature, which is not as relevant as the air temperature to human health. UHeat is a tool developed by Arup to quantify the UHI and study the effectiveness of mitigation. It can quickly model and compare different mitigation strategies to help identify effective actions in reducing UHI effects and provide air temperatures at hourly intervals.



Urban heat snapshot of London

UHeat utilises a wide range of input data which influence UHI, including land cover, albedo (surface reflection), population density, altitude, and climate data. Land cover is produced by an in-house deep learning classification model that uses Very High-Resolution imagery (30cm) to ensure individual trees, gardens and small features that are pivotal to calculating and quantifying UHI are captured. All other data can be derived from open data sources to build a detailed picture of the city. Zonal statistics of the data are extracted across a hexagonal grid either over a focused area of interest or an entire city. UHeat uses the Surface Urban Energy and Water Balance Scheme (SUEWS) model developed by the University of Reading.

Working alongside the Institute for Risk and Disaster Reduction at University College London, Arup has integrated this academic model into UHeat, a tool to provide rapid analysis that can be used to understand the impact of cities on urban heat. Verification has been performed in two ways for each location depending on data availability. The primary method is the verification of air temperatures against all local weather stations. If local weather station data isn't available, then Landsat surface temperature data is used and compared for any available collection dates.

UHeat aims to provide city authorities, urban planners, developers, and any relevant stakeholder with vital information on urban heating to improve city planning, public health and resilient infrastructure. Urban results can be compared to a rural environment that models the temperature as if no buildings or roads had been built in the area to evaluate the Urban Heat Island Intensity. Furthermore, if a user is interested in testing mitigation strategies for their city, then inputs such as land cover through increased greening and changes in surface albedo can be adjusted to identify the potential benefits.

The UHeat tool has already been used by cities across the world to explore the heating effects of their infrastructure and mitigation scenarios. The Arup 'Urban Heat Snapshot' calculated the UHI of London, Los Angeles, New York, Madrid, Cairo, Mumbai, Singapore, Melbourne and Brisbane.

The study identified hotspots and cool spots across each city, classifying land cover in these areas using the input EO data to understand the contributions of different parameters to the UHI effect.

UHeat bridges the gap between academic models and real-world analysis, filling a market need. The close relationship Arup has with the academics working on the climate model enables frequent feedback on its functionality. The model is also developed on Amazon Web Service's Sagemaker Geospatial, which provides hugely scalable processing and allows the project to rapidly grow and adapt. Climate change projection data can also be implemented in the tool to analyse how UHI effects are increasing with higher future temperatures.

Such complex heat modelling has historically been reserved largely for academics and has been a time-consuming exercise. UHeat bridges this gap, drawing on the technical work and methods developed by researchers and combining them with increasing amounts of city data available through remote sensing. This means that city leaders, designers, and planners can rapidly understand what interventions will be effective in bringing down temperatures in their local climate and context at a street, neighbourhood, and city scale — protecting people from extreme heat in their cities.

ACHIEVED OUTCOMES

Social

The effects of heat are broad, but not everyone is impacted equally by heat. Often, it's the most vulnerable who are most impacted by these UHI hotspots. Income inequality can play a role in people's ability to cool themselves, and lower-income neighbourhoods are less likely to have greenery and shade from trees to keep their streets cool. Arup conducted an 'Urban Heat Snapshot' survey in 9 cities to understand cities' UHI hot spots and created a snapshot of how digital tools can be used to address UHI. The results of their survey were stark. In two cities it showed a massive 8°C difference in temperature between areas in close proximity to one another. It also highlighted the risks for vulnerable people, for example in the area studied in Madrid, approximately 492,000 children and older people were identified as living within UHI hot spots of 7°C or more. This is worrying, given these groups' vulnerability to heat-related illness.

Environmental

UHeat promotes NbS and advanced digital technologies to enhance infrastructure resilience, improve biodiversity, and reduce carbon emissions. Tools like Terrain, an AI land-use digital mapping tool, help cities rapidly understand how land is being used and guide green infrastructure, while AI-based systems monitor structural health, extending the lifespan of buildings and reducing the need for demolition. Uheat also supports biodiversity through satellite imagery and Biodiversity Net Gain (BNG) tracking. By optimising designs and using lower carbon materials, Uheat achieves substantial carbon savings, aligning with global sustainability goals to decarbonise infrastructure and combat climate change.

Economic

UHeat delivers economic benefits by providing city planners with precise data to mitigate UHI effects, reducing energy costs, improving infrastructure resilience, and increasing property values. The tool identifies cost-effective interventions, such as NbS and retrofitting buildings with 'cool roofs', which lower energy consumption and reduce health-related expenses.

For example, UHeat has been used in Tanzania's largest city, Dar es Salaam, to evaluate its future urban heat profile based on major projected increases in population. This has helped show the potential of NbS to tackle the UHI effect, reducing temperatures across the city and has demonstrated how mitigation strategies can result in potential long-term cost savings and enhanced urban livability.

Arup has also used UHeat with the UK's Greater London Authority on a city-wide programme of retrofitting existing buildings with 'cool roofs' – featuring reflective paint and solar photovoltaic (PV) panels – to help guard against rising temperatures due to climate change. The project shows how adaptations at scale will lower temperatures inside and outside buildings, resulting in positive impacts on health and wellbeing for Londoners, while providing cost savings. Building on this work, Arup has published a report commissioned by the Mayor of London on Properties Vulnerable to Heat Impacts in London: Prioritisation for Adaptation Interventions, which looks at which of the city's 'essential properties' such as schools, hospitals, care homes, residential buildings and neighbourhoods would be most impacted during periods of high temperatures.

WEATHERING THE STORM – ADAPTING VICTORIA'S INFRASTRUCTURE TO CLIMATE CHANGE

Sector

Built Environment
Energy
Coastal Resilience & Climate Adaptation
Transport

Resilience Phase

PREPARE RESPOND RECOVER ADAPT

Highlights

Biodiversity
Road safety

Project owner
Infrastructure Victoria

Project start/completion
Nov 2022 – Apr 2024

Location
Victoria, Australia

Communities impacted
Rural, Coastal, Urban

Hazards mitigated
All hazards

Case study provided by:

INFRASTRUCTURE VICTORIA

LEARN MORE

Infrastructure Victoria is an independent infrastructure advisory body to the Victorian Government in Australia. It examined Victoria's current climate policy framework to see how departments and agencies are assessing resilience and adapting infrastructure. 'Weathering the Storm: Adapting Victoria's Infrastructure to Climate Change' is a series of research reports published in April 2024. It assesses the benefits of adapting government-owned or -managed infrastructure to the changing climate. This project is designed to help governments decide how and where to invest in adapting infrastructure.

ABOUT THE PROJECT

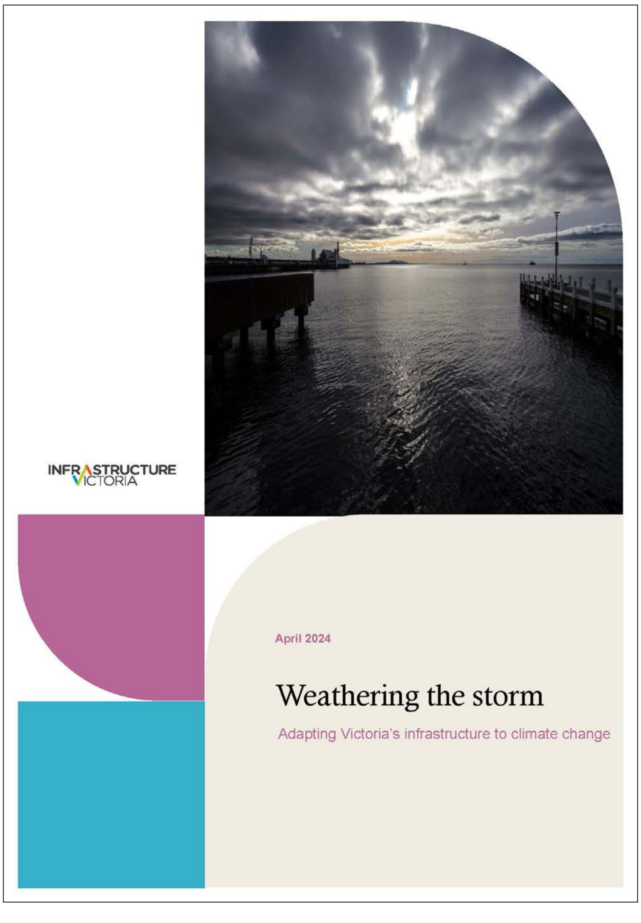
Infrastructure Victoria employed geospatial analysis and hazard mapping technologies for the research. It was able to identify 40 climate-related risks to Victoria's government-owned and regulated infrastructure. The research assesses climate risks and evaluates the ROI for adaptation measures. It also recommends actions to improve resilience and adaptation throughout the lifecycle of infrastructure. These recommendations can better equip Victoria's infrastructure for more frequent and severe weather, keep communities safer, minimise disruptions and reduce disaster recovery costs.

Underinvesting in infrastructure resilience leads to higher economic, social and environmental costs over time. Victorians are already paying the costs of a changing climate. Extreme weather damage costs Victoria about AUD 2.7 billion a year. Without action to better protect infrastructure, it will fail more often, harming and costing people and businesses. This project demonstrates that early investment in infrastructure adaptation measures can minimise the costs of recovering from extreme events and reduce the harm to people and the environment.

Carefully selected measures can help communities, services and supply chains prepare for extreme weather and recover faster. They can start in the most vulnerable locations.

Infrastructure Victoria's research geospatially mapped the location of infrastructure and overlaid data representing hazards. It used these findings to compare the economic case for different adaptation measures. The analysis found that the benefits of investing in infrastructure adaptation can outweigh the costs of repairing and rebuilding after extreme weather events. It observes that some adaptation measures cost very little and can deliver a positive ROI.

The economic analysis method modifies the cost-benefit analysis approach. It uses both direct and indirect costs and benefits, maladaptation, embodied emissions associated with the different adaptation measures, and the potential of different adaptation pathways. This method can be repeated across different sectors, infrastructure types and locations. A diverse mix of stakeholders were consulted throughout the project. They included Victorian Government departments and agencies, asset managers, academics, regulators and research bodies.



Physical adaptation measures were divided into four categories:

- Higher-cost investment options, such as large-scale projects requiring the construction of infrastructure or higher-cost materials
- Lower-cost investment options, including nature-based solutions
- Maintenance, including increasing periodic maintenance and preventative maintenance
- Hazard management solutions, such as communication and early warning systems, removal of hazards and temporary structures.

Seven recommendations were outlined to help the Victorian Government better assess and prepare infrastructure for more frequent and extreme weather:

1. Boost priority and oversight for infrastructure adaptation
2. Coordinate and standardise climate projections
3. Use asset management systems to improve resilience
4. Integrate climate risk into government risk management
5. Align climate and financial risks to infrastructure
6. Update business case and investment guidance
7. Build confidence that good adaptation measures will receive funding

If adopted, these recommendations can support infrastructure asset managers to better consider adaptation in their normal activities and throughout the lifecycle of infrastructure. Moreover, the research shows how to assess the risks from extreme weather and compare different solutions to better protect infrastructure assets. This can help governments decide how and where to invest in infrastructure adaptation efforts.

To demonstrate this research, Infrastructure Victoria conducted an economic analysis of two infrastructure sectors: electricity distribution and road networks. In each sector, it tested the potential ROI for different adaptation measures.

Three scenarios were selected for assessment: damages to roads from floods, accessibility to roads from bushfires and landslides, and extreme winds for electricity distribution.

The research conducted a multicriteria analysis to create a shortlist of 20 adaptation measures. It considered community impacts during construction and maintenance, recovery time, cost of construction, level of net impact on the environment and maladaptation risks. It also assessed the embodied carbon associated with the production and transportation of materials for each adaptation measure.

A CBA demonstrated that adaptation measures can have a positive ROI. It was also found that governments can benefit from coordinating and sequencing different adaptation measures.

Infrastructure Victoria showed how technologies can enhance decision-making for climate resilience and adaptation. When assessing the damages to roads from floods, measures included:

- Foamed bitumen stabilisation, a road pavement treatment which improves its strength.
- Upgrading the road grade and improving drainage to absorb one-in-20-year flood events. Implementation involves several measures, including raising the road level above the projected flood level in 2070 under RCP8.5, improvements to transverse drainage systems and additional culverts installed to ensure adequate water flow and prevent waterlogging on the road surface.
- Staged upgrading of the road grade and improving drainage now to absorb one-in-20-year flood events, and upgrade in future to absorb one-in-100-year flooding.
- Building a new raised road viaduct over a floodplain or waterway to provide a stable and safe route for critical traffic, while minimising the impact on the surrounding landscape and protecting against potential future flood events.
- Using water-sensitive urban design to harness natural infrastructure and systems to capture, treat and manage stormwater runoff from roads.
- Increasing preventative maintenance to preserve pavement condition and extend the road's life.
- Programming road rehabilitation involves more frequent extensive repairs and maintenance to improve the overall condition of the road.
- Using intelligent transport system solutions and rerouting to prevent further damage to roads after flooding. This includes ITS solutions such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technologies, rerouting traffic to alternative routes, and limiting heavy loads on roads that may have been weakened by the storm.

The following technologies were examined to reduce service interruptions of roads caused by bushfires and subsequent rainfall-induced landslides:

- Remediate 2 high-risk slopes with flexible barriers to protect the road from landslides, debris or rockfalls.
- Remediate 11 high and moderate-risk slopes with flexible barriers. The slope remediation includes the installation of flexible debris barriers for cuttings and soil nails to stabilise embankments.
- Fire-resistant plants that do not burn easily from continuous flame or the first wave of a bushfire.
- Fire breaks to reduce the rate of spread and intensity of fire.
- Increased programmed drainage clearing and vegetation management such as clearing or controlled burns to reduce embankment slope failure after bushfires.
- Immediate post-fire responsive drainage clearing for embankments and cuttings along slopes following a bushfire to reduce landslide risk.
- Post-fire erosion protection and slope stabilisation using seeding, matting and drainage clearance.
- Risk management plan including intelligent transport system signage alerts, disaster response planning procedures for inspections, maintenance and rehabilitation.

The flooded road case study showed preventative maintenance produced AUD 5.10 for every AUD 1 spent in current climate conditions. This increased to AUD 8.29 under future conditions, using a 7% discount rate. The study showed this extended the lifespan of infrastructure assets, helping to avoid costly repairs and premature replacements. Adaptation solutions including foamed bitumen stabilisation, water-sensitive urban design, and programmed maintenance, also performed well under current and future scenarios.

The bushfire-impacted road case study factored in a subsequent landslide event. It showed that programmed drainage clearing and vegetation had a high ROI under current (5.88 benefit-cost ratio) and future (11.52 benefit-cost ratio) scenarios.

The analysis also showed that damage to, or degradation of, electricity distribution lines due to extreme weather is a high-rated climate risk for electricity infrastructure. The case study consisted of a service area of 2,000 customers and found that replacing existing overhead conductors with overhead insulated cables had a positive ROI (AUD 1.16 for every AUD 1 spent).

This research confirmed that adaptation measures can produce a compelling investment case when direct, indirect and intangible costs and benefits are considered. It shows that site-specific analysis is essential for assessing potential adaptation measures and highlights how economic evaluation can guide adaptation action. However, not all measures will generate a positive ROI due to their specific location, features or local climate conditions.

Using the results from this research, the Victorian Government can prioritise the infrastructure exposed to the highest climate risks. It can sequence adaptation actions by prioritising assets or combinations of actions.

For example, the government can combine planting new vegetation and clearing drains after a fire to help stabilise slopes and minimise erosion. The right sequencing of adaptation measures can create better outcomes and help with forward-planning budgets.

Infrastructure Victoria's project shows that climate risk assessments are useful for determining which assets to prioritise. Asset managers need to analyse local environmental conditions and forecasts to consider how climate change will affect specific infrastructure assets. Site-specific analysis can not only identify potential impacts on people but also biodiversity, ecological health and cultural heritage. Investing in adaptation measures, including nature-based solutions, can reduce the damaging impacts of more frequent and extreme weather on local environments.

This research better equips Victoria’s infrastructure for more frequent and severe weather conditions, supporting more efficient and reliable decision-making before, during and after hazard events.

CLIMATE RISK INTELLIGENCE PLATFORMS

The private sector will play a critical role in advancing emerging digital technologies and making them accessible for climate action. Here, we spotlight some SMEs that are leading the way in harnessing technology to embed climate risk and resilience in decision-making.

SME 1
TERRAFUSE AI

Terrafuse, a spin-out from Lawrence Berkeley National Laboratory, employs advanced machine learning to create hyperlocal climate risk scores, enhancing resilience against climate-induced hazards. The technology integrates AI with EO data, providing ultra-fine spatial resolutions to predict the likelihood of extreme events such as wildfires.

Terrafuse's approach involves processing billions of EO data points to understand and model the complex interdependencies between environmental variables and climate risks. Their AI models analyse over 50 environmental conditions, including building density, vegetation type, and fuel moisture, to forecast potential climate impacts at a specific location. By embedding the physics of the atmosphere, the system improves prediction accuracy.

Terrafuse has implemented its AI-driven technology through partnerships with various sectors, including insurance companies. The Wildfire AI model, for example, provides risk scores on a scale of 1 to 10 at resolutions as fine as 30 m^2, enabling businesses to make precise, location-specific decisions. These scores are integrated into clients' systems via an API, allowing seamless access to geospatial visualisations and data analytics.

LEARN MORE

SME 2
TOMORROW.IO

Tomorrow.io is leveraging advanced AI, machine learning, and satellite data to deliver precise weather and climate risk insights. The company's Resilience Platform™ integrates weather intelligence into business operations, enabling organisations to predict, adapt, and build resilience against escalating weather events.

The proprietary technology processes data from a global constellation of radar satellites, combining it with AI models to provide hyperlocal, real-time weather predictions and climate risk assessments. Their platform offers a suite of advanced probabilistic ensemble models, which generate detailed forecasts for various weather scenarios, including thunderstorms, tornadoes, wind, hail, and flood threats. The system is capable of visualising forecast event timings and providing critical severity information, facilitating advanced preparation for weather impacts.

The Resilience Platform™ is designed to integrate weather intelligence directly into operational processes, using AI-driven dashboards and predictive workflows. This automation allows organisations to create and manage resilience goals tailored to their specific needs. Automated protocols, which trigger alerts and standardised response workflows for weather events, ensure that businesses can respond swiftly and effectively.

In addition, Tomorrow.io's solutions have yielded significant financial benefits for clients. For instance, a Fortune 500 retailer saw an 11% improvement in fulfilment rates, while JetBlue saved $30 million annually through weather-informed decision-making. The platform also supports long-term resilience strategies, helping organisations withstand the increasing frequency and intensity of climate-related disruptions.

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tomorrow.io

SME 3
ONE CONCERN

One Concern is a climate resilience technology company that uses advanced AI, data science, and catastrophe modelling to provide precise risk analytics and insights for businesses. Their approach focuses on creating a digital twin of the world to map and measure vulnerabilities, particularly those that impact operations outside of physical property boundaries, such as power outages and supply chain disruptions.

One Concern's platform offers highly granular assessments, differentiating properties and businesses based on their specific vulnerabilities and potential exposure to climate risks. The technology is particularly valuable for industries such as financial services and insurance, where precise risk quantification and foresight are essential for decision-making. One Concern's solution extends beyond merely offering data; it provides businesses with predictive insights and resilience metrics that help them measure, prepare for, and capitalise on climate-related challenges.

The company's proprietary One Concern DNA™ API enables (re)insurers to capture direct and contingent business interruption (BI) risks. This is crucial, as BI losses are a significant driver of financial loss during disasters such as hurricanes. One Concern's BI risk scores help insurers understand and quantify both Property Damage Business Interruption (PDBI) and Contingent Business Interruption (CBI). These scores provide insights into the underlying causes of downtime, such as infrastructure impairments or community-level impacts, allowing insurers to make informed underwriting and pricing decisions.

In a study with a major insurer, One Concern's BI risk scores correlated with 90% of actual BI losses in terms of geographic distribution and claim size. This demonstrates the platform's accuracy and effectiveness in capturing risk metrics that can directly inform pricing strategies, risk management, and operational planning for insurers.

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SME 4
FATHOM

Fathom, a pioneering company in water risk intelligence, originated from discussions among University of Bristol researchers in 2012 regarding the challenges of developing comprehensive flood models. Established in 2013, initially under the name SSBN, Fathom has since aimed to transform water risk management by combining cutting-edge research in hydrology, hydraulics, and remote sensing with data-driven methodologies. The company's primary focus is on providing transparent, scientifically robust flood models, making it a valuable resource for diverse sectors including humanitarian aid, insurance, international development, and engineering.

Fathom's Global Flood Cat model is particularly noteworthy; it quantifies financial risks across multiple flood perils — pluvial, fluvial, and coastal — using a detailed approach that includes millions of potential flood events. This model not only aids risk managers in assessing financial exposure but also offers extensive customisation options to meet specific needs. By maintaining strong ties to academic research, Fathom ensures that its flood models are grounded in the latest scientific findings, thus equipping its clients with the tools necessary to navigate the increasing complexities of climate change and water-related risks. This commitment to innovation and collaboration positions Fathom as a leader in advancing climate-resilient infrastructure through effective water risk management.

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SME 5
URBAN FOOTPRINT

UrbanFootprint offers a Resilient Decision Intelligence Platform designed to address the complexities of building climate-resilient and equitable infrastructure. The platform integrates comprehensive, context-rich data on the urban and natural landscape, enabling energy utilities, financial institutions, government agencies, and private corporations to make data-driven decisions that optimise resource allocation and investment planning.

The platform is underpinned by a cloud-native software system that synthesises a variety of curated and enriched datasets. These datasets provide users with a unified, standardised view of the American urban landscape. UrbanFootprint's technology incorporates three foundational data collections:

- **The Built Environment Foundation** offers an up-to-date view of land use, buildings, transportation, and infrastructure across the United States. With data on 160 million land parcels, this resource provides users with granular insights into site conditions at multiple scales, from individual parcels to counties, which is crucial for assessing community context and development potential.
- **The People & Vulnerabilities Foundation** compiles data on community and household characteristics, focusing on evaluating vulnerabilities to climate risks and environmental stresses. By aligning and modelling this data, the platform assesses eligibility for public and disaster assistance, offering a detailed view of the demographic and social factors that influence climate resilience.
- **The Climate & Hazards Foundation** provides a comprehensive analysis of current and future climate risks. It models environmental hazards, including extreme weather events, and assesses their impact on communities, infrastructure, and ecosystems. By integrating this data, UrbanFootprint equips users with the tools to forecast and mitigate risks at local, regional, and national levels.

UrbanFootprint's platform is built to deliver clear and actionable insights across various sectors. For energy providers, it supports infrastructure investment planning by mapping community vulnerabilities and climate risks. For governments, it aids in the efficient distribution of resources, such as food and housing, by identifying areas of greatest need. Investors and insurers can leverage the platform to evaluate risks tied to climate change and urban development trends, ensuring that their strategies align with evolving community resilience requirements.

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SME 6
GEOADAPTIVE

GeoAdaptive is a multidisciplinary firm composed of experts in territorial economic strategy, participatory scenario planning, and sustainable development. With a mission to foster inclusive societies and sustainable livelihoods, GeoAdaptive tackles pressing issues such as underdevelopment, poverty, and climate change. Its expertise spans urban, regional, and national scales, and it integrates advanced geospatial intelligence and technology to design strategies that are anticipatory, preventive, and sustainable. These strategies are aimed at optimising resource allocation, identifying spatial synergies, and leveraging place-specific opportunities to create transformative impacts. The firm's diverse project portfolio covers areas such as sustainable and resilient infrastructure, coastal and blue economy resilience, climate adaptation, social inclusion, and decarbonisation strategies.

GeoAdaptive works in over 30 countries, including rapidly growing regions in Latin America, Asia, and the Caribbean. Projects range from climate adaptation planning in Florida to facilitated risk communication and adaptation strategies for small island nations, such as the Republic of Marshall Islands, through the creation of a 3D online portal visualising the impacts of sea-level rise and storm surges, including population displacement and infrastructure damage.

GeoAdaptive's approach is rooted in leveraging big data analytics, design thinking, and economics to understand the complexities of sustainability challenges. The firm employs geospatial methods of analysis to produce comprehensive assessments of social, economic, political, and environmental dynamics unfolding within territories. These insights guide decision-makers, ensuring that interventions are tailored to the specific needs of communities and regions, with a focus on long-term development goals.

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2.2 KNOWLEDGE FOR ACTION AND CAPACITY BUILDING

Through knowledge-sharing and capacity-building activities, we can accelerate the uptake of tools, resources, and skills for advancing sustainable and resilient infrastructure in communities across the globe. Knowledge transfer, open-source tools and training programmes can all play a role in empowering local communities as well as communities of practice in working towards climate-resilient solutions for infrastructure. The following examples of tools, resources and knowledge transfer initiatives can empower practitioners and local communities to leverage technology for climate-resilient, sustainable infrastructure solutions. They also feed into the Sharm El-Sheik Adaptation Agenda cross-cutting theme of planning, providing universal access to the tools and infomation required to integrate climate risks into decision-making from local to global levels.

ACCELERATING CITY CLIMATE ACTION THROUGH GEOSPATIAL DATA

The Global Covenant of Mayors for Climate Action (GCoM) and World Geospatial Industry Council's report, Accelerating City Climate Action Through Geospatial Data, delves into the transformative role of geospatial technologies in enhancing climate resilience for urban environments. As cities grapple with the increasing frequency and intensity of climate-related hazards, the integration of geospatial data and tools has become critical. The report argues that cities must leverage such technologies to build resilience, reduce GHG emissions, and effectively plan for future impacts based on robust evidence and data-driven decision-making.

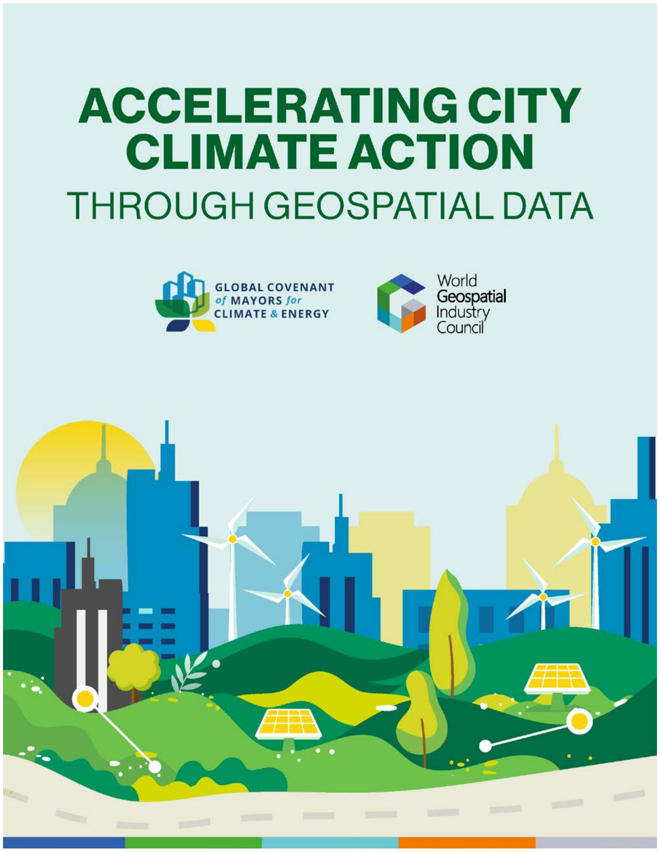
The publication identifies three priority areas for cities aiming to accelerate climate action:

1. Applying geospatial data at the city scale for Climate Risk and Vulnerability Assessments (CRVAs) and Greenhouse Gas Emissions Inventories (GHGIs);
2. Exploring geospatial solutions through urban demonstrations; and
3. Advancing the monitoring and evaluation of climate action using geospatial tools.

These areas are crucial for city planners and policymakers, who require access to accurate and up-to-date information to guide their actions. By focusing on these domains, the report highlights the potential of geospatial technologies to integrate and manage complex data, allowing cities to better understand their vulnerabilities, set appropriate climate targets, and measure progress effectively.

A key component of the report is its emphasis on the role of digital twins and GIS as enablers of climate resilience. One notable example of the application of these technologies in cities is Gothenburg, Sweden, which has developed a comprehensive digital platform known as 'Virtual Gothenburg'.

This initiative represents a digital twin of the city, integrating data on ecological, economic, and social factors. The platform serves as a testbed for innovation, allowing Gothenburg to simulate climate scenarios and evaluate the effects of various adaptation strategies in real time. The city uses this tool to manage and monitor its infrastructure, water systems, and energy usage, ensuring a proactive approach to urban planning. By utilising digital twinning technology, Gothenburg effectively models the potential impacts of sea-level rise, urban heat islands, and extreme weather events, helping city officials implement data-driven solutions that enhance resilience.



GLOBAL COVENANT of MAYORS for CLIMATE & ENERGY

World Geospatial Industry Council

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AI FOR AFRICA: USE CASES DELIVERING IMPACT

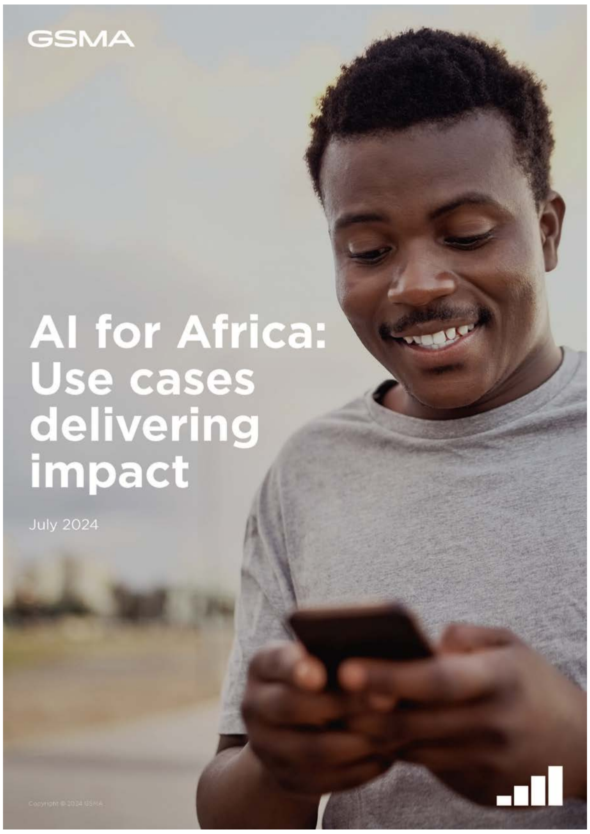
A new report from the GSMA, a global organisation representing Mobile Network Operators (MNOs) and the broader mobile ecosystem, identifies AI-enabled use cases and solutions that address development challenges related to agriculture and food security, energy and climate action.

The report AI for Africa: Use cases delivering impact, funded by the UK Foreign, Commonwealth and Development Office (FCDO), provides a landscape overview of the AI ecosystem in Kenya, Nigeria, and South Africa to identify gaps and opportunities to improve the enabling environment and development of AI-enabled use cases. The three countries are technology leaders on the continent and in their sub-regions and present significant potential to leverage AI for development.

The GSMA has identified over 90 AI use case applications across the three countries in selected sectors, highlighting the diverse ways that AI is being utilised in Africa. Kenya and Nigeria lead in the deployment of AI for development purposes and boast dynamic tech ecosystems despite facing significant development challenges. South Africa, with a more advanced economy, has focused its AI applications beyond development sectors. The report explores key requirements for each use case and assesses its potential for impact, scale as well as constraints.

To address the objectives of the research, the GSMA investigated the following key pillars of the AI ecosystem to understand how they impact the development and scalability of use cases:

- Digital economy foundations, encompassing digital infrastructure, human capital and skills, and policy and regulation;
- AI fundamentals, including data, AI-specific skills, and compute capacity;
- Crosscutting enablers, such as partnerships, financing mechanisms, and research and development.



The report highlights that predictive AI, which uses statistical analysis and machine learning, is the most widely used AI technology across the three focus countries. It is commonly applied to tasks like weather forecasting, crop yield optimisation, and energy management — critical for regions heavily dependent on agriculture and with energy gaps. In contrast, only three instances of generative AI, which creates new data or content, were identified.

As AI technologies continue to evolve, there is tremendous potential for further development across Africa. With improved data-sharing frameworks and continued investment, AI could play a transformative role in addressing critical challenges and driving sustainable development across the continent. This report offers a set of recommendations for key stakeholders, pinpointing ways to catalyse the development of the AI ecosystem to deliver impact in the region.

GSMA

UK International Development
Partnership | Progress | Prosperity

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CLIMATE AND ENVIRONMENTAL DATA PLATFORMS

SHORT CASE STUDIES

THE CLIMATE ATLAS OF CANADA

The Climate Atlas of Canada is an interactive tool for citizens, researchers, businesses, and community and political leaders to learn about climate change in Canada. It combines climate science, mapping and storytelling to bring the global issue of climate change closer to home, and is designed to inspire climate action at local, regional, and national levels.

The climate model data presented in the Atlas is primarily sourced from the Pacific Climate Impacts Consortium (PCIC). PCIC has provided downscaled projections of daily temperature and precipitation data from 24 climate models using two carbon emission scenarios.

The Atlas explains what climate change is, how it affects Canada and what these changes mean for communities. Various aspects of climate change can be explored using maps, graphs and climate data for provinces, local regions and communities across the country. Importantly, climate science is made to be understandable and meaningful through plain-language description and analysis.

Documentary videos, collaboratively developed with local and Indigenous knowledge holders as well as other experts, help make local sense of the global issue of climate change. These voices of lived experience provide personal perspectives that complement the climate data and help explain the reality and the meaning of climate change in Canada.

Climate Atlas of Canada

24 Global Climate Models

40+ Map Variables

400+ Interviews

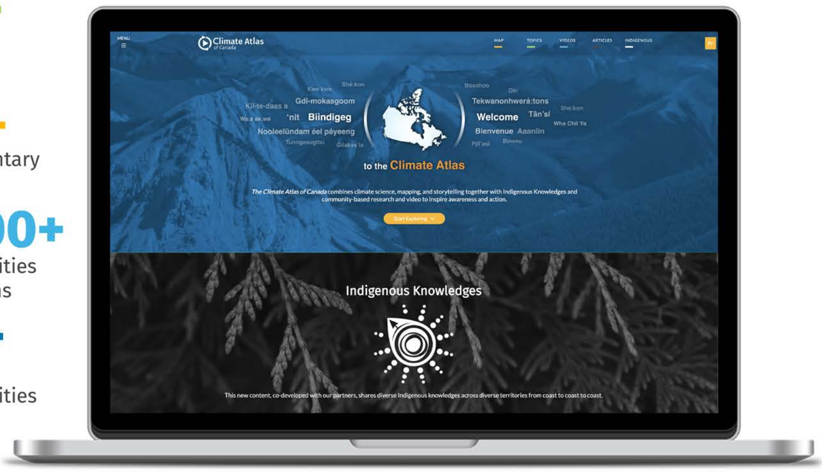
80+ Documentary Films

500+ Map Layers

2000+ Towns, Cities & Regions

600+ First Nations Communities

50+ Inuit Communities



Prairie Climate Centre
From Risk to Resilience

THE UNIVERSITY OF WINNIPEG

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THE COMMUNITY RISK ASSESSMENT DASHBOARD

The Community Risk Assessment Dashboard (CRA) is a tool developed as part of New York City's Hazard Mitigation Plan. It is designed to help residents and decision-makers assess how various hazards, such as coastal storms, extreme heat, and flooding could impact different neighbourhoods across the city. The dashboard integrates historical data with current hazard information, enabling users to visualise risks in real time.

Additionally, the CRA Dashboard provides resources and strategies, known as mitigation actions, to reduce potential risks. For instance, it offers guidance on flood protection, cooling strategies for extreme heat, and earthquake preparedness for communities and building owners. The dashboard includes a range of datasets, such as thermal imagery for heat vulnerability, 1% annual chance floodplain, and historical earthquake epicentres, making it a comprehensive risk assessment and planning tool. Risk reports can also be produced for each community district in New York City to highlight the hazards and vulnerabilities at the neighbourhood level and suggest strategies that communities can take to reduce their risk.

This platform aims to support better-informed policy decisions and empower communities to take action in mitigating risks from climate-induced and climate-exacerbated disasters.

The Community Risk Assessment Dashboard

NYCEM
New York City Emergency Management

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CDRI GLOBAL INFRASTRUCTURE RESILIENCE INDEX (GIRI)

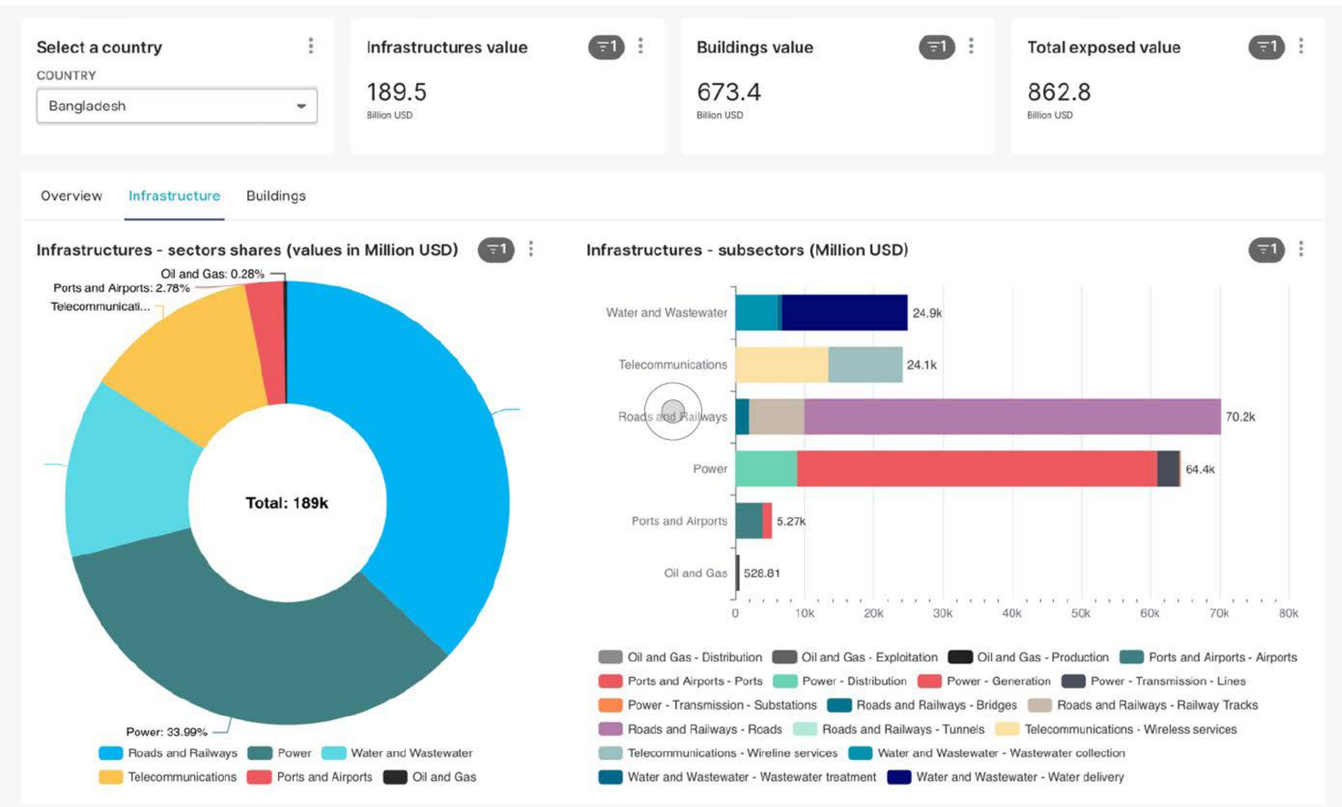
The Global Infrastructure Resilience Index (GIRI) is a pioneering initiative by the Coalition for Disaster Resilient Infrastructure (CDRI), aimed at evaluating and enhancing the resilience of critical global infrastructure sectors. Developed with the support of various scientific and technical organisations, GIRI is the first fully probabilistic risk assessment model designed to assess infrastructure resilience across sectors such as power and energy, transport, telecommunications, water, and social infrastructure like health and education.

GIRI's main objective is to provide globally comparable metrics that evaluate how well infrastructure systems can withstand and recover from disasters, particularly in the face of climate change. The index evaluates risks from multiple hazards such as earthquakes, tropical cyclones, floods, landslides, droughts, and tsunamis. The model accounts for various climate change scenarios, offering insights into the likely impacts on different infrastructure sectors in every country and territory worldwide.

Using cutting-edge probabilistic risk modelling, GIRI estimates the potential Average Annual Loss (AAL) for each infrastructure type, factoring in hazard exposure and vulnerability. This approach allows countries to understand their contingent liabilities — the potential losses they could incur due to infrastructure failures from disasters — enabling more informed investment and planning decisions for disaster resilience. Governments can use this information to allocate resources for contingency planning, improve infrastructure codes and standards and focus on long-term investments that prioritise adaptation and resilience measures.

Technologically, GIRI integrates big data analytics and climate models to provide high-resolution risk assessments. The platform uses a combination of geospatial data layers, enabling stakeholders to examine risks in specific locations through an interactive, user-friendly platform. This data-driven approach supports real-time decision-making, offering a global public good by making risk metrics publicly available to governments, investors, and planners.

Country data on the Global Infrastructure Resilience Index



This also allows for the development of innovative financial instruments, such as catastrophe bonds and risk-based insurance schemes.

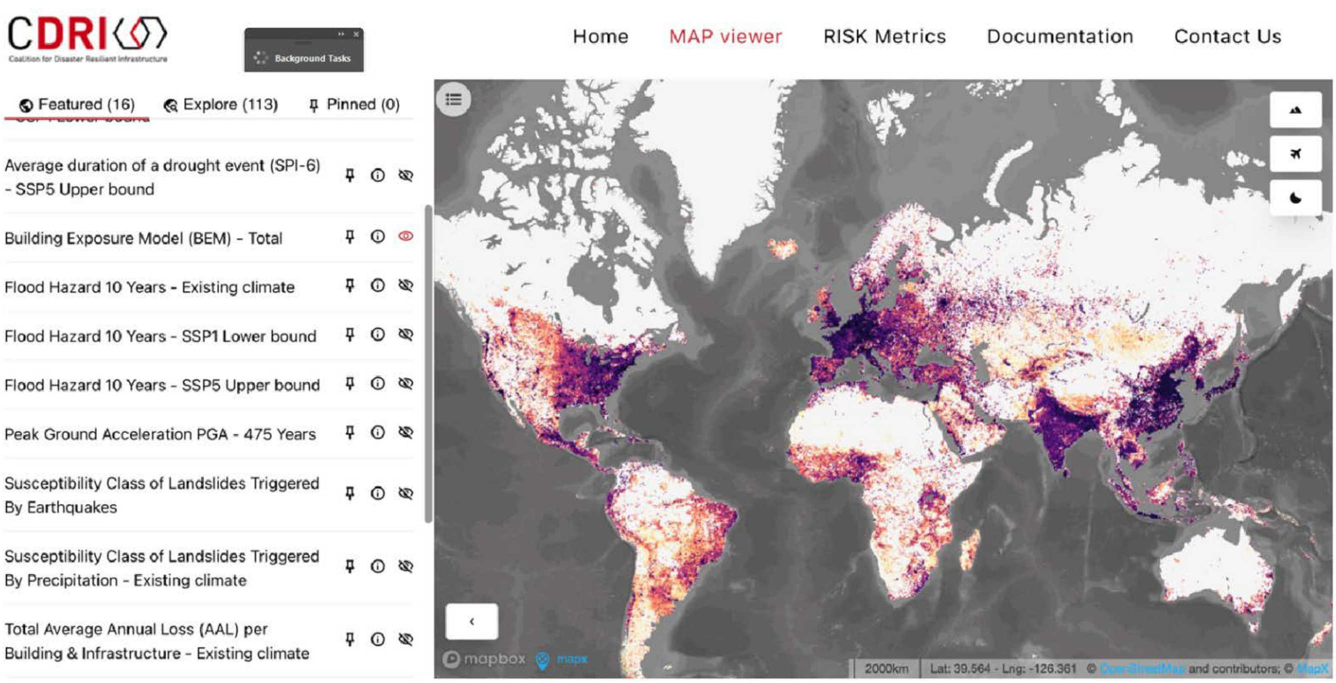
Additionally, the GIRI platform features a digital dashboard where users can interact with risk data, create customised reports, and compare risk metrics across different regions and sectors. This allows for deeper analysis of resilience performance curves, illustrating how infrastructure systems can absorb, respond to, and recover from adverse events.

GIRI data is being used around the world to improve infrastructure resilience. CDRI is leveraging GIRI data to enhance its Fiscal Risk Assessment (FRA) study, by estimating the direct physical risks posed to infrastructure assets due to disasters, including climate change-related events. The FRA study covers four countries: Fiji, India, Mauritius, and Nepal.

The International Water Management Institute (IWMI) is utilising GIRI data to strengthen its Climate Smart Governance (CSG) dashboard. This enables government agencies and financial institutions to prioritise investments by assessing the vulnerability and resilience of critical infrastructure using GIRI indicators.

Furthermore, five countries — Bhutan, Chile, Ghana, Madagascar, and Tonga — are using GIRI data to prioritise their infrastructure governance. Additionally, institutions like UNESCAP and UNDRR are employing GIRI within their country engagement and risk assessment projects and programmes. There has also been growing interest from Financial Institutions in using GIRI as a model for calculating their assets and investments at risk.

The Global Infrastructure Resilience Index map viewer



THE RESILIENT PLANET DATA HUB

The Resilient Planet Data Hub is a global initiative aimed at building resilience to climate change by providing open-access data, tools, and guidance for climate risk measurement and decision-making. The initiative is a partnership between the UNDRR, the Insurance Development Forum (IDF), and the University of Oxford to address a significant gap in resilience policy and capital decision-making.

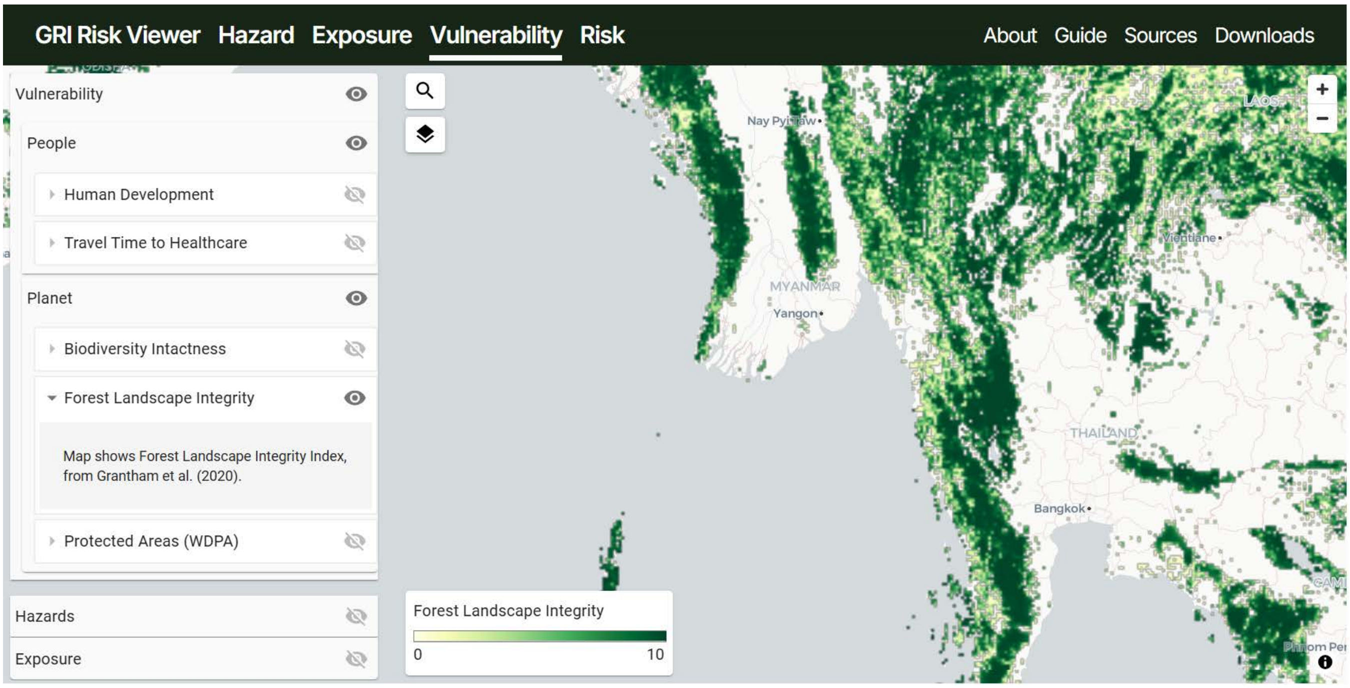
Launched at COP28, the initiative is an effort to create a global framework for measuring climate risk. The Hub seeks to develop a standardised and transparent system for assessing climate risks and geo-hazards, utilising an open data approach and bringing people together to create a common language of risk.

A key component of this initiative is the Global Resilience Index (GRI) Risk Viewer, a data portal focused on hazards, exposure, vulnerability, and risk to infrastructure and people globally.

It supports climate adaptation decision-making by identifying vulnerabilities and risks in current and future scenarios. The GRI Risk Viewer helps governments, communities, and investors adapt to climate change by providing open data on climate hazards and vulnerabilities for visualisation and download, fostering shared understanding. This enables the identification of key opportunities, social vulnerabilities, and needs, offering a starting point for risk analysis. The platform helps screen risks to assets and populations, aiding solutions for society, economy, and nature.

Looking ahead, the Resilient Planet Data Hub will continue enhancing its datasets, improving climate risk analysis, and customising use cases to demonstrate physical climate risk disclosures and prioritisation of investment in adaptation. Its goal is to scale the use of climate risk metrics and ensure long-term sustainability.

Global Resilience Index Risk Viewer dashboard



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NASA'S EYES ON THE EARTH

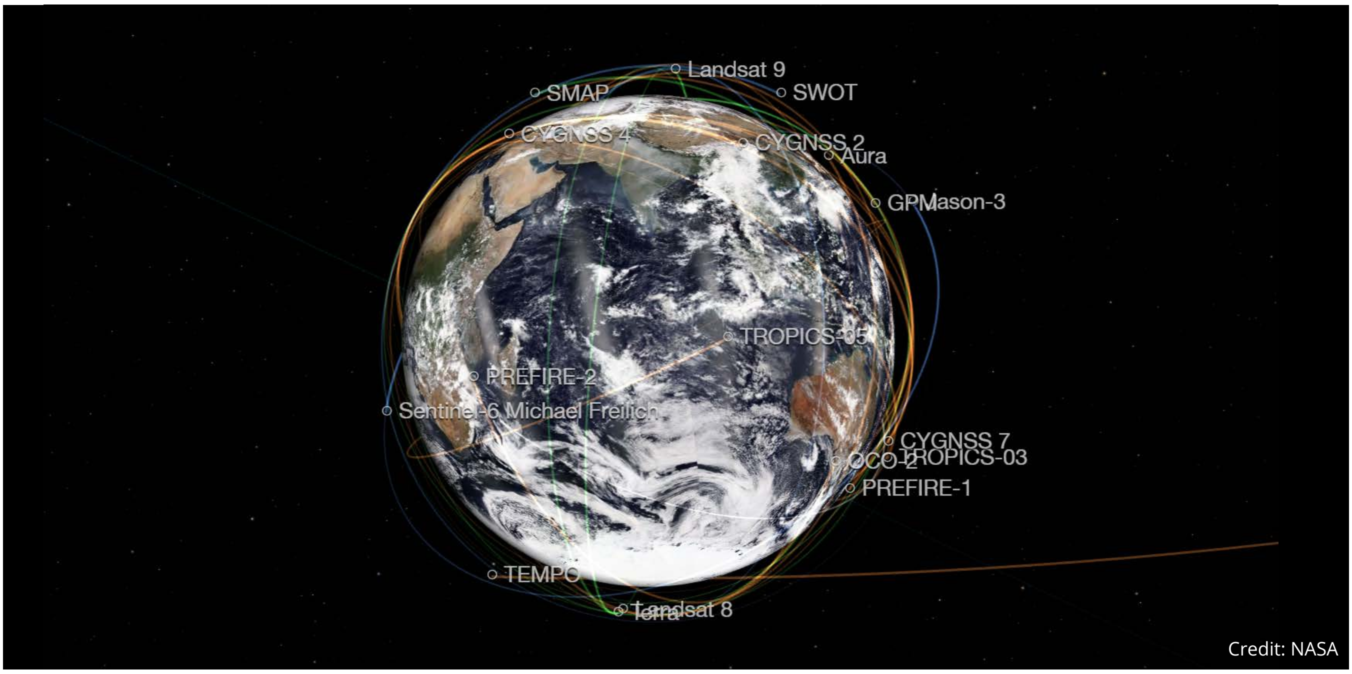
NASA's Eyes on the Earth platform is an interactive, 3D visualisation tool that enables users to explore near real-time Earth science data collected by NASA's satellites. Accessible via a web browser, it allows users to monitor a range of Earth's vital signs, including carbon dioxide, precipitation, sea level, soil moisture, and atmospheric conditions.

The platform offers a unique way to visualise and track environmental phenomena and their impacts, making it a valuable tool for understanding climate change and its effects on a global scale. For example, Eyes on the Earth can provide snapshots of significant events in the natural world, such as tropical storms, the impacts of a northern California fire, and even the scale of a phytoplankton bloom off of New Zealand.

The platform can be used by infrastructure practitioners and planners to:

- Monitor Vital Climate Data: Decision-makers can track key metrics such as precipitation, soil moisture, and sea level rise, which are essential for assessing the vulnerability of infrastructure, especially in coastal areas prone to flooding or erosion.
- Assess Environmental Risks: By visualising near real-time data on greenhouse gases, extreme weather events, and natural phenomena such as fires, dust storms, and volcanic eruptions, planners can better assess risks to infrastructure and design solutions that account for these hazards.
- Long-Term Climate Trends: With the ability to play back historical data spanning over 20 years, the platform helps users identify long-term climate patterns and trends, which can inform future-proof infrastructure designs that adapt to changing environmental conditions.
- Real-Time Satellite Tracking: Infrastructure planners can also use data from NASA's Earth-observing satellites to track ongoing environmental changes, allowing for dynamic responses to help protect critical infrastructure.

NASA's Eyes on the Earth is a powerful resource for making informed, data-driven decisions in planning, building and protecting infrastructure from the impacts of climate change.



Credit: NASA

Project owner(s)
NASA

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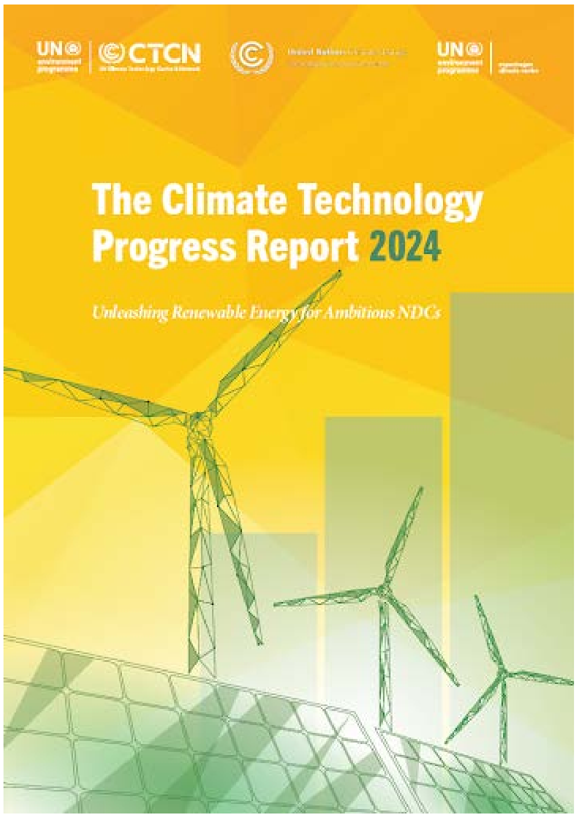
THE CLIMATE TECHNOLOGY PROGRESS REPORT 2024



The UN Environment Programme Copenhagen Climate Centre (UNEP-CCC) in collaboration with the Climate Technology Centre & Network (CTCN) and the UNFCCC Technology Executive Committee (TEC) have published the Climate Technology Progress Report 2024 (CTPR 2024).

The CTPR provides an update on the progress made towards tripling renewable energy capacity by 2030 and on the enabling conditions to create this transition, through a technology transfer and systems approach lens, particularly in view of countries' preparations of updated Nationally Determined Contributions (NDCs) to be submitted in 2025.

Further to this, it is expected that at COP 29, a pivotal decision on the New Collective Quantified Goal (NCQG) will be made. This new goal aims to channel more funds into urgent climate actions in developing countries. It will support the implementation of low-carbon, climate-resilient technologies across sectors. By increasing financial resources, the NCQG is intended to empower developing countries to enhance their climate ambitions, particularly as they prepare for the next round of NDCs in 2025.

The report also provides scientifically credible and policy-relevant assessments of different aspects of technology development and transfer in key areas, including those related to feasibility, finance, innovation, and governance; delivers information relevant to the UNFCCC process and to the implementation of the Paris Agreement; and strengthens informed country action on technology transfer including the creation of enabling environments. Furthermore, the report takes a global approach with a regional breakdown of the results, to allow an assessment of the overall progress on technology development and transfer. With this approach, it is possible to gain insights for tailoring interventions based on specific needs such as infrastructure and regulatory environments, governance, and financial structures.

The report outlines several renewable energy technologies that meet both mitigation and adaptation goals, while also contributing to the SDGs. This relates to electricity generation and energy storage, and to the resilience and reliability of these systems. Meanwhile, solar and wind power are highly feasible considering institutional, economic, technological, geophysical, and socio-cultural dimensions. However, data gaps may still be limiting regional expansion. The report also showcases that countries need to set more ambitious renewable energy targets in their updated NDCs. This involves aligning national policies to achieve the goal of tripling renewable energy capacity by 2030. Hence, institutional capacity, along with supportive policies, regulations, and standards, needs to be strengthened to improve the overall feasibility of those technologies that scored the least.

UN environment programme | copenhagen climate centre

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GAMING FOR CLIMATE RESILIENCE

With over three billion players worldwide, gaming technologies represent a powerful tool to reach diverse audiences. The Atlantic Council's Climate Resilience Center (CRC) is tapping into this community and fostering awareness about climate resilience by integrating climate-related scenarios into video game narratives and other gaming technologies. Through innovative partnerships and game development, the CRC is educating and equipping players with the knowledge needed to address climate impacts.

Video games immerse players in different realities, where they can experience the consequences of climate threats and experiment with adaptive solutions. In these virtual environments, players face challenges like extreme heat and learn how to build communities and restore digital ecosystems. The CRC's approach taps into the interactive nature of gaming, making climate science and resilience strategies accessible and engaging for players across all demographics. By tackling climate issues through gaming, users gain the skills, language, and understanding needed to apply these lessons to real-world situations.

A prominent example of this collaboration is the Extreme Heat Series, developed in partnership with Minecraft Education. This series educates students on how to manage and respond to heat-related emergencies. Players learn to recognise signs of heat exhaustion and implement simple interventions like hydration and cooling mechanisms. The game also teaches about urban climate solutions, such as the benefits of parks, shade structures, and reflective surfaces in reducing heat in cities. There are also other games which educate students on community engagement. Power Grid Hero, for instance, challenges players to manage the power supply for a growing community, while coping with extreme heat waves. This game helps players understand how energy systems work and teaches them strategies for building climate-resilient infrastructure. Through engaging, interactive gameplay, players are empowered to become part of the solution to global climate challenges.

The CRC has also set up the Gaming Center of Excellence in an effort to connect key stakeholders from the games industry, climate resilience, and social impact design to drive innovation and progress in climate games. This Center runs Climate Game Workshops and provides knowledge and resources to support game teams and publishers. A recent report, Gaming for climate action, serves as a guide for designers, developers, and publishers with insights and best practices for creating games that spur climate action.

In Minecraft: Heat Wave Survival, players learn how to protect their village from the notorious Heat Dragon. The dragon is a visual representation of heat, helping students around the world understand that extreme heat is a clear and present danger.

Atlantic Council | Climate Resilience Center

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HEAT ACTION PLATFORM

To address the issue of cities worldwide facing the growing threat of extreme heat, the Heat Action Platform has emerged as a valuable tool for capacity-building in heat resilience, enabling city officials, practitioners, and financial institutions to assess, plan, implement, and evaluate heat resilience projects. Developed by the Atlantic Council's Climate Resilience Center in partnership with the UN Environment Programme's Cool Coalition, the Global Covenant of Mayors for Climate and Energy, Mission Innovation and RMI, the Platform reflects input from local and international stakeholders across sectors.

By connecting local practitioners and community leaders with global experts, the platform promotes the co-development of heat resilience solutions that meet specific local needs. It also helps identify the environmental, economic, and social benefits of various interventions, guiding cities in implementing effective heat adaptation and mitigation strategies. It is available in English, Spanish, Hindi, and Tamil.

The Platform is organised by three stages: Assess, Plan and Implement, each of which hosts three modules. The Baseline Heat Risk Assessment is the first module in the Assess stage. This module equips users with a structured approach to analysing current and future temperatures, identifying critical data sources, and mapping relevant stakeholders. This assessment helps cities understand the distribution of heat exposure across neighbourhoods and identify areas where resilience investments are most needed. For example, by comparing urban and non-urban temperature patterns, cities can assess the impact of the UHI effect and prioritise cooling strategies. Overlaying heat maps with population data or health vulnerability information allows cities to identify the most at-risk communities, guiding targeted investments in heat resilience.

The baseline assessment also emphasises the importance of identifying and utilising high-quality data sources, as heat-related datasets are often insufficient for decision-making. For instance, while land surface temperature data is readily available, it may not accurately reflect the temperatures that people experience. Air temperature data, which is more relevant for assessing public health impacts, can be harder to obtain. The Heat Action Platform encourages cities to partner with local organisations or academic institutions to access or generate the necessary data for heat resilience planning.

Stakeholder mapping is another key aspect of this module. Extreme heat affects various sectors, and coordinated action is essential to avoid fragmented responses. Through participatory stakeholder mapping, cities can engage communities, public and private sector partners, and academic institutions to ensure inclusive and comprehensive heat resilience strategies. This process helps identify relevant stakeholders, including those whose voices may be underrepresented, and establish relationships that are critical for long-term project success. As part of the module, there are more case study resources on how heat baseline assessment is conducted in other parts of the world, including Europe, the United States and India.

By integrating heat considerations into existing projects, policies, and processes, the Heat Action Platform promotes early partnerships and 'easy wins' that can build momentum. From urban tree planting initiatives to regulatory changes, these early actions set the stage for larger-scale heat resilience efforts, helping cities prepare for the growing risks posed by extreme heat.

Atlantic Council | Climate Resilience Center

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PORTWATCH

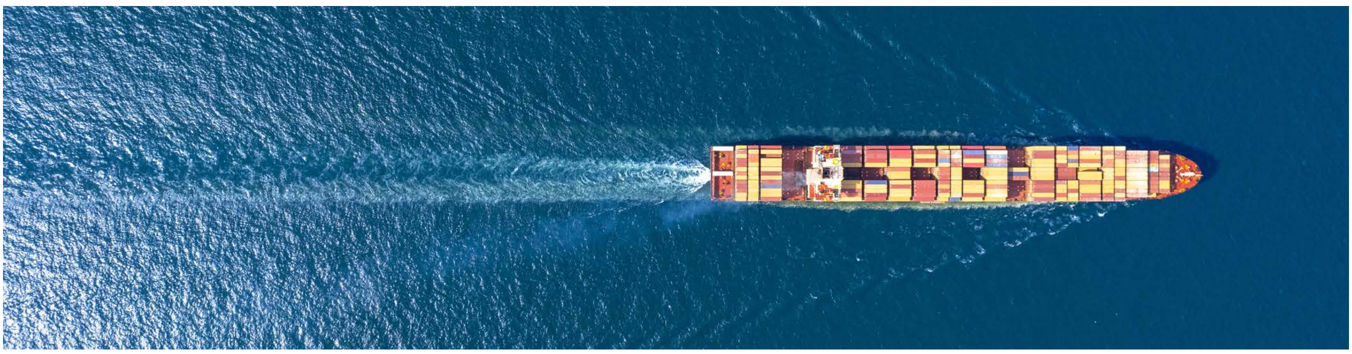
PortWatch is a platform that leverages satellite data and big data analytics to assess the impact of disasters on both domestic and international trade, providing crucial insights for policymakers, development partners, and the public. Developed through a partnership between the IMF and the Environmental Change Institute at the University of Oxford, PortWatch is designed to analyse how disruptions to port activity affect global supply chains, enabling timely responses to disaster-related trade shocks.

A core function of PortWatch is its disaster alert system, which delivers email updates in the wake of major disasters. These alerts provide real-time information on realised and anticipated trade disruptions, helping stakeholders respond swiftly and effectively to minimise economic fallout. The service is accessible to anyone and is free of charge, ensuring that vital information reaches those who need it most in the aftermath of a crisis.

PortWatch also allows users to explore the broader implications of port disruptions. By simulating both real and hypothetical port closures, users can assess the indirect spillover effects on other countries within the global maritime trade network. This spillover analysis reveals which sectors and regions are most vulnerable to trade shocks, providing valuable guidance for strategic responses to safeguard economic stability. For example, the temporary closure of a key port due to an extreme weather event could lead to trade bottlenecks, causing ripple effects across multiple countries dependent on the flow of goods through that port.

In addition to immediate disaster response, PortWatch offers climate scenario analysis, which models the impacts of future climate extremes on port infrastructure. By analysing risks across 1,400 ports worldwide, PortWatch provides detailed insights into the vulnerability of the global maritime network to cyclones, floods, and other climate-induced disasters. This analysis is critical for informing long-term resilience planning, helping countries prioritise investments in their most vulnerable infrastructure. For instance, ports in regions prone to cyclones could be identified as high-risk, prompting governments to bolster protective measures and improve recovery strategies to reduce trade disruptions in the future.

PortWatch's data-driven approach is instrumental in fostering international dialogue on disaster resilience. With support from institutions such as The World Bank, the World Trade Organisation, and the UN Global Platform, the platform helps bridge the gap between research and actionable policy solutions. By highlighting which sectors and ports are most at risk, PortWatch encourages collaborative efforts to strengthen the resilience of global trade networks against both present and future climate challenges.



Project owners
International Monetary Fund

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SERVIR SEA

Building on the success of SERVIR-Mekong, SERVIR Southeast Asia (SERVIR SEA), was co-created by USAID, NASA, and the Asian Disaster Preparedness Center (ADPC).

Established in January 2023, SERVIR SEA aims to enhance environmental, economic, human, and climate resilience across Southeast Asia through expanded climate action supported by satellite data and geospatial information for decision-making.

Working in collaboration with regional organisations, SERVIR SEA focuses on strengthening the capacity of seven countries — Cambodia, Indonesia, Laos, Myanmar (Burma), the Philippines, Thailand, and Vietnam — to integrate geospatial information into decision-making, planning, and communication efforts aimed at building climate resilience.

At its core, SERVIR SEA is committed to institutionalising technical capacity within governments and civil society to ensure geospatial information is effectively utilised to manage climate risks. This commitment is reflected in the programme's efforts to improve access to user-tailored geospatial data and products, while also developing new tools and models that address the unique, on-the-ground priorities of the region. By fostering a deeper understanding of climate-related risks, SERVIR SEA equips policymakers and practitioners with the information they need to adapt to the impacts of climate change.

A key example of how SERVIR SEA delivers practical solutions is through its development of the Rainstorm Tracker and Mekong X-Ray applications, which strengthen the Mekong River Commission's (MRC) Flash Flood Bulletin. The Rainstorm Tracker provides real-time storm severity updates, allowing MRC to monitor rainfall events daily and anticipate potential flash floods. Mekong X-Ray complements this by mapping exposure and vulnerability data, enabling targeted alerts for high-risk areas. Integrated into MRC's Flash Flood Guidance System, these tools make the Flash Flood Bulletin more actionable, helping authorities deliver timely, precise flood alerts to protect communities across the Mekong region.

Another key application is the Air Quality Tracker, which demonstrates SERVIR SEA's commitment to health-focused climate resilience by integrating satellite and ground-based data to monitor PM 2.5 levels, detect fires, and manage transboundary haze across Southeast Asia. This tool empowers decision-makers and the public alike with timely air quality information, allowing them to take proactive steps to protect health during pollution events.

SERVIR SEA works closely with local and regional institutions to ensure that the data and tools it provides are not only scientifically robust but also tailored to the specific needs of each country. Recognising the importance of mainstreaming Gender Equality and Social Inclusion (GESI), SERVIR SEA ensures that data and information consider the diverse needs of communities, effectively 'connecting space to the village'.

Through this approach, the programme helps to break down silos and promote the sharing of data and expertise across borders, which is particularly important in a region where climate risks often transcend national boundaries. This collaborative approach not only supports Southeast Asian countries in adapting to the challenges of a changing climate but also enables them to identify opportunities for sustainable development.

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THE STATE OF FIRETECH

The State of FireTech Report (2022) and Annual Updates (2023, and 2024 forthcoming) explore how FireTech — the development and application of science, data, and technology innovations — is playing an increasingly critical role in building infrastructure resilience as part of wildfire risk management. The reports highlight key emerging trends and technological innovations aimed at mitigating the impacts of wildfires in sustainable and equitable ways.

The frequency and intensity of wildfires are growing due to changing fire regimes and climate patterns. The development of climate-resilient infrastructure now requires integrating technologies that can better detect, predict, and manage these extreme fire events. The 2023 report categorises FireTech solutions into five areas, each addressing different aspects of wildfire management and prevention and bringing unique technological innovations to the table.

Connectivity technologies, including satellite, aerial, and ground sensors, play a crucial role in early wildfire detection and communication. For instance, sensor networks and IoT applications enhance situational awareness, offering real-time data on fire risks. This allows for faster, more coordinated responses, potentially saving lives and reducing property damage. One application mentioned is Team Awareness Kits, which uses data from multiple sources to improve decision-making in firefighting efforts.

Digital technologies enable more comprehensive data collection, modelling, and analytics related to wildfire hazards and risks. AI and cloud-based services are driving this digital revolution, offering tools for mapping fire-prone areas, predicting fire behaviours, and facilitating community resilience. These systems integrate various types of data to create sophisticated predictive models, allowing communities to take preemptive measures.

Mechanisation is transforming how fires are managed and controlled on the ground. The report highlights the use of robotics and drones to augment firefighting efforts. UAVs and ground-based robots, equipped with cameras and sensors, are increasingly being deployed to assess risk, assist fire crews, and automate tasks such as vegetation management. This mechanisation reduces the risk to human firefighters and increases operational efficiency in combating wildfires.

Materials technology is a growing field in FireTech, with advancements in fire retardants, suppressants, and structural retrofits. Building materials that can withstand extreme heat and retard fire spread are critical in protecting infrastructure in fire-prone areas. This includes the development of foam-based fire suppressants and organic compounds that are used both in response to wildfires and in controlled burns aimed at reducing fuel loads in vulnerable landscapes. Moreover, innovations in structural retrofitting—such as fireproof vents and roof materials—help safeguard homes and businesses, contributing to climate-resilient urban development.

Fintech solutions have emerged as an unexpected but vital part of wildfire resilience. This includes insurance innovations and carbon markets that provide financial tools for managing fire risks. As wildfires become more frequent, insurers are exploring new ways to calculate risks and provide coverage, while carbon credit markets incentivise responsible land management practices, such as prescribed burns.

The report also provides an overview of policy developments and funding tailwinds for science, data, and technology and includes recommendations for next steps including scaling up cost-effective investments in physical protection to reduce wildfire losses, ensuring well-functioning insurance markets to absorb risk that cannot be cost-effectively mitigated, and addressing disparities in pre-fire protections and post-fire recovery for socially vulnerable and marginalised populations.

The State of FireTech is the result of discussions of the Wildfire Technology Funders Group — a diverse group of philanthropists, corporates, and impact investors. The report has been conceptualised and compiled by Wonder Labs with support from The Gordon and Betty Moore Foundation's Wildfire Resilience Initiative.

GORDON AND BETTY MOORE FOUNDATION

Wonder Labs

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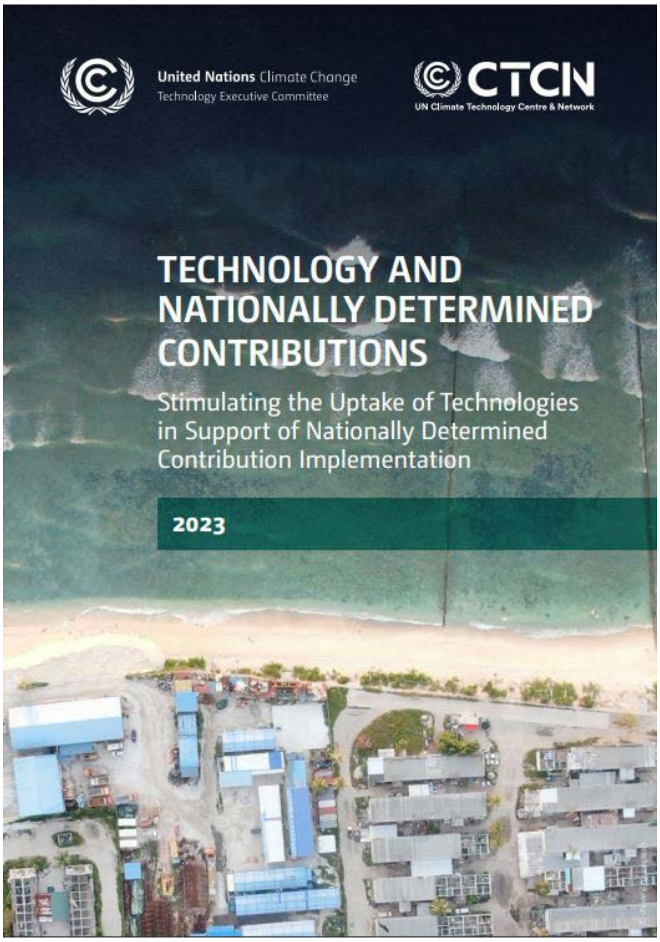
TECHNOLOGY AND NATIONALLY DETERMINED CONTRIBUTIONS

The UNFCCC-TEC and the CTCN report Technology and Nationally Determined Contributions focuses on policy-level technology needs that address both climate mitigation and adaptation, as highlighted by the technology needs of Parties in their nationally determined contributions (NDCs). The report emphasises the integration of cross-cutting technologies, which often serve multiple sectors, ensuring the dual benefits of adaptation and mitigation. The publication reveals that most technology needs outlined in NDCs pertain to energy, agriculture, water, and waste management, with a growing trend towards digital and ecosystem-based technologies.

National Adaptation Plans (NAPs) are particularly crucial in the technology needs assessment process. NAPs help countries identify adaptation priorities, and their linkage with NDCs strengthens climate technology implementation at both policy and operational levels. For instance, the development of NAPs can concretise adaptation components of NDCs, enabling the incorporation of sector-specific technologies such as advanced hydrological monitoring systems and early warning systems, which address climate variability challenges like floods and droughts. Effective policy coordination between NAPs and NDCs is vital for coherent and actionable climate strategies.

Among the highlighted success stories, Uruguay's COASTAL-NAP provides an example of how technology can be mobilised for climate adaptation in coastal zones. Uruguay used advanced climate modelling and vulnerability assessment technologies to address coastal erosion and flooding risks. The integration of these tools allowed for the detailed mapping of vulnerabilities, which informed the country's coastal adaptation strategies and secured further financing from the Green Climate Fund. This case illustrates how linking NDCs and NAPs can facilitate the development and uptake of locally relevant technologies, enhancing national climate resilience.

Another example is Bhungroo, a water storage technology in India aimed at smallholder farmers. This technology addresses the dual challenges of floods and droughts by enabling water harvesting and storage underground. It contributes to India's NDC targets by enhancing agricultural resilience while improving water management. Bhungroo's success in rural areas showcases the importance of community-led technology adoption and the role of women as local leaders, which not only enhances adaptation outcomes but also promotes gender equality. This model demonstrates how technology tailored to local contexts and supported through inclusive policies can achieve broader socio-economic benefits.



Overall, the report emphasises that strong linkages between NAPs, NDCs, and policy frameworks are essential for successful technology uptake. Establishing enabling environments through regulatory measures, financial support, and inclusive planning processes can significantly advance climate technology deployment, particularly when aligned with the objectives of NAPs and NDCs.

A previous report from TEC, Compilation of Good Practices, focuses on international collaborative research, development and demonstration (RD&D) of climate technology. It presents a compilation of case studies showcasing RD&D partnerships and initiatives, from which it draws good practices and lessons learned.

Project owners

The UNFCCC Technology Executive Committee (TEC
Climate Technology Centre and Network's (CTCN)

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USING VR TO ENHANCE DISASTER PREPAREDNESS

In recent years, the Caribbean has faced an alarming increase in the intensity and frequency of disasters, particularly hurricanes. Since 2017, the region has been battered by three Category 5 hurricanes — Irma, María, and Dorian — causing substantial damage across the islands. In response, the Trinidad and Tobago Red Cross Society (TTRCS) has adopted innovative technological solutions to engage communities and improve their capacity to respond to such emergencies.

Despite the high stakes, the TTRCS encountered significant challenges in drawing community attention to the importance of disaster preparedness. The recurrence of smaller, less impactful natural events, such as hurricanes and earthquakes, often desensitised residents, leading to complacency regarding disaster risks. Over time, the lack of urgency in addressing these dangers resulted in delayed responses when more severe events occurred, thereby increasing vulnerability to catastrophic outcomes.

A TTRCS staff member demonstrates a VR-based education system aimed at illustrating the impacts of disasters and promoting preparedness. Source: Solferino Academy.

To address these challenges, the TTRCS turned to virtual reality (VR) technology as a means of education and awareness-raising. This approach culminated in the development of a VR-based education system aimed at illustrating the impacts of disasters and promoting preparedness. The VR experience immerses participants in simulated disaster scenarios, allowing them to experience the physical sensations associated with events like hurricanes and earthquakes in a safe environment. By navigating these virtual scenarios, users not only witness the potential devastation but also learn essential skills and knowledge for effective disaster response.

The TTRCS created three distinct virtual worlds that depict various disaster scenarios relevant to Trinidad and Tobago. Among these scenarios are a magnitude 8 earthquake and a Category 5 hurricane, along with a dedicated training centre for disaster preparedness. The development of these virtual environments involved consultations with experts from the IFRC Solferino Academy, Hollywood design studios, and local innovators, ensuring that the simulations were both realistic and educational. By utilising existing technologies on the market, the TTRCS integrated a smartphone-based VR experience complemented by VR headsets for a more immersive experience.

Initially targeting young people, the VR programme unexpectedly proved effective across a broader demographic, reaching both adults and children. The initiative, supported by funding from the Empress Shōken Fund, has successfully engaged over 2,300 individuals. Between October 2020 and August 2021, 1,285 participants completed the virtual training, receiving certificates that validate their newfound knowledge and skills.
This outcome underscores the potential of VR technology not only as a tool for engaging younger audiences but also as an effective medium for broader community education on disaster preparedness.

Following the success of the VR programme, the TTRCS is currently developing a mobile application based on augmented reality (AR) to further enhance disaster preparedness among school-aged children and communities. This initiative reflects a growing recognition of the role technology can play in facilitating learning and engagement, particularly in addressing complex issues like disaster preparedness in vulnerable regions.

Project owner
Trinidad and Tobago Red Cross Society

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UPSKILLING WOMEN ENGINEERS FOR DISASTER RESILIENCE IN TIMOR-LEST

An initiative led by Humanitarian OpenStreetMap Team (HOT), in collaboration with Feto Enginhera, focuses on empowering women engineers in Timor-Leste through capacity building in geospatial technology and disaster resilience skills. The initiative aimed to increase the participation of women in the engineering sector and strengthen community resilience to climate impacts.

Timor-Leste, a small island nation in Southeast Asia, faces significant climate vulnerabilities due to its mountainous terrain and seasonal heavy rainfall, leading to frequent floods and landslides. Women in such communities often bear the disproportionate brunt of these events, especially those who are already vulnerable, such as girls or women with disabilities. This project addresses the gap in gender-responsive DRR strategies by providing women with the skills needed to engage meaningfully in climate resilience efforts.

The project consisted of a two-phase training programme designed specifically for members of Feto Enginhera, a locally-led group of volunteer women seeking to promote equal participation in the country's engineering sector. The first phase involved a series of workshops organised with the Association of Geographic Information System Group (G-SIG) and HOT's Asia-Pacific Open Mapping Hub. The training focused on building skills in open mapping tools like OpenStreetMap (OSM), using HOT's Tasking Manager, and data visualisation. The workshops covered the application of geospatial data for DRM and the integration of gender-sensitive approaches within disaster preparedness and response frameworks. The participants were also introduced to key project management skills, allowing them to implement and manage mapping initiatives effectively.

Credit: Feto Enginhera

In the second phase, participants applied their new skills through outreach activities, engaging with different communities and schools across Timor-Leste. These outreach sessions included public workshops where members of Feto Enginhera shared information about their work and the importance of women-centred DRR approaches. They also distributed 'Dignity Bags' — pre-assembled kits containing essential products for women and girls during emergencies — ensuring that gender-specific needs are considered during disaster response efforts. Additionally, the participants conducted a three-day field exercise to collect and analyse data, resulting in 151 new entries in OSM. These entries helped create maps that identify key infrastructure, such as evacuation centres and areas vulnerable to flooding, which are crucial for community-based disaster planning and resilience building.

The project had a significant impact, not only in building skills but also in contributing to local communities' resilience. By the end of the project, 116 women were trained, and they successfully mapped 3,969 buildings and 35km of roads. This data is now integrated into OSM, making it accessible for future use and enhancing DRM efforts in the country. Through this project, participants gained proficiency in essential tools such as Kobo Collect, Kobo Toolbox, and Q-GIS software, which are pivotal for data collection and analysis in geospatial projects. The comprehensive nature of this training empowered women engineers, giving them the skills to map infrastructure and assess building capacities, which are critical for planning evacuations and understanding community vulnerabilities.

Credit: Feto Enginhera

FETO ENGINHERA | Humanitarian OpenStreetMap Team | Open Mapping Hub ASIA-PACIFIC

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2.3 COLLABORATIVE INITIATIVES

Systemic problems require systemic solutions; the collective challenge of climate change demands a collaborative approach to problem-solving that spans sectors, regions, and disciplines. This kind of approach will help to bridge divides between practitioners, communities, and governments, and catalyse key actors into moving forward on adaptation and mitigation measures. Allowing for diverse contributions to problem-solving will result in solutions that are holistic, transferable, and inclusive at their core.

THE ASCE-NOAA TASK FORCE FOR CLIMATE RESILIENCE IN ENGINEERING PRACTICE

A partnership between the American Society of Civil Engineers (ASCE) and the National Oceanic and Atmospheric Administration (NOAA) seeks to ensure that the nation's infrastructure is climate-ready. The partnership is facilitated by the Center for Technology and Systems Management (CTSM) of the Department of Civil and Environmental Engineering of the University of Maryland (UMD) at College Park.

The ASCE-NOAA Task Force for Climate Resilience in Engineering Practice, working with the ASCE Subcommittee on Climate Intelligence for Codes and Standards (CICS), built on work published as part of the ASCE's Climate Resilient Infrastructure: Adaptive Design and Risk Management Manual of Practice, to examine key weather and climate impacts of relevance to engineering practice. Three climate hazards were identified as a primary focus for updating building standards and codes: extreme temperature, linear wind, and extreme rainfall with implications to coastal storms as a fourth hazard.

In 2022, the Task Force organised a two-part workshop on Leveraging Earth System Science and Modeling to Inform Civil Engineering Design focused on three climatic hazards and one region of relevance to engineering practice. Part I of the workshop addressed extreme temperature and intense rainfall, and part II addressed straight-line winds and coastal hazards. This workshop report is based primarily on the outcomes of structured discussions between climate scientists and engineers during the lengthy breakout sessions of those workshops.

On February 1, 2023, the two organisations signed a Memorandum of Understanding (MOU), followed the next day by a leadership summit between the two organisations at which preliminary outcomes from these workshops were presented. The MOU more formally spells out the respective roles of ASCE and NOAA going forward and states as the major objectives of the partnership to:

Improve cooperation in developing and delivering climate data, information, science and tools required by civil engineering and allied professionals in order for them to design, build, operate, and maintain climate-resilient infrastructure.

Facilitate ASCE's efforts to update its published and educational content to reflect the best available climate information.

ASCE is identifying its need to incorporate the best available science into the next generation of civil engineering codes, standards, and manuals of practice. In turn, NOAA is identifying how it may be able to aid in satisfying this need with its capabilities over both the near and long term. A formal collaboration between the nation's largest provider of climate information and the world's largest civil engineering professional society will advance the use of NOAA-produced climate science, understanding and data products within engineering practice for the design and construction of climate-resilient infrastructure, especially during the development and updating of ASCE codes and standards.

This partnership will help to ensure that the design and construction of new and retrofitted infrastructure accounts for, and is resilient against, the increased hazards associated with the changing climate. By helping to ensure that the design and construction of infrastructure are informed by the best available scientific understanding of future weather and climate conditions, this effort should increase the pace of climate adaptation and reduce design, construction, and maintenance costs as well as the costs of climate-induced or climate-enhanced disasters.

ASCE AMERICAN SOCIETY OF CIVIL ENGINEERS

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

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THE EARLY WARNINGS FOR ALL INITIATIVE: STRENGTHENING DISASTER RISK KNOWLEDGE

The Early Warnings for All (EW4All) initiative is co-lead by the World Meteorological Organization (WMO) and UNDRR. The initiative aims to ensure universal protection from hazardous hydrometeorological, climatological and related environmental events through life-saving multi-hazard early warning systems (MHEWS), anticipatory action and resilience efforts by the end of 2027. One-third of the world's population is not currently protected by EWS and only half of the world's countries had an adequate MHEWS when the initiative was launched in 2022.

A MHEWS is an integrated system that informs people that hazardous events are approaching. It can also inform how governments, communities, and individuals can act to minimise socio-economic impacts by allowing those at risk to act in sufficient time and in an appropriate manner.

The realisation of the initiative requires scale-up and coordination of investments and actions across four pillars:

1. Disaster risk and knowledge management (led by UNDRR)
2. Detection, observation, monitoring, analysis, and forecasting (led by WMO)
3. Warning dissemination and communication (led by the International Telecommunication Union)
4. Preparedness and response capabilities (led by the IFRC).

WMO is mandated to provide support on strengthening of Pillar 2 related activities. At the start of the EW4All initiative, some countries operated with only basic monitoring and forecasting capacity, and others only had very basic capacity. In particular, critical gaps have been identified in surface and upper air meteorological observations across Africa, parts of the Pacific, and west of Latin America. Furthermore, only 56% of countries use hazard, exposure, and vulnerability data in their forecasts, and only 67% of WMO members have warning and alert systems available 24/7.

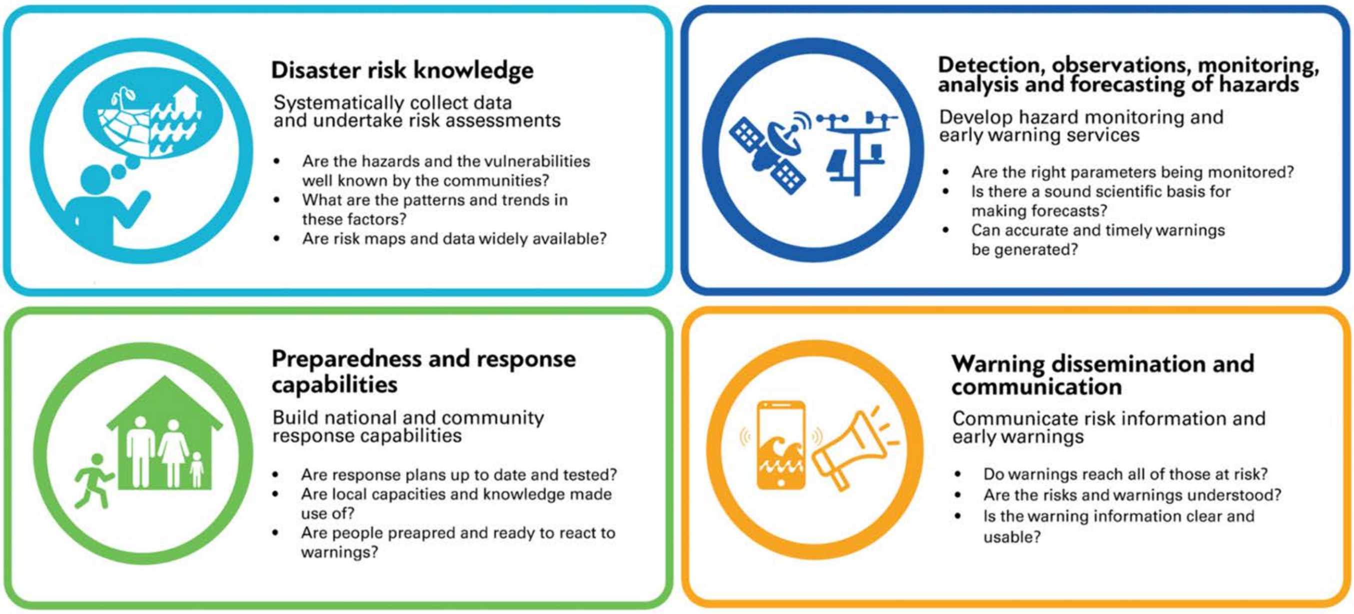
As such, the Pillar 2 Implementation Plan focuses on achieving 5 outcomes:

- Improving data quality and access;
- Sharing data worldwide;
- Enhancing forecasting capabilities and warning dissemination;
- Proactive measures for early action; and
- Establishing robust leadership frameworks.

The effective implementation of MHEWS rests on the use of technology. EWS rely on the worldwide sharing of data collected from the Earth's surface and remote sensing, which is then analysed by highly advanced supercomputing modelling centres. These centres run numerical models which simulate how different parts of the Earth System, such as weather, hydrology, oceans, and cryosphere, interact with each other. From these simulations, predictions are made that allow National Meteorological and Hydrological Services to provide accurate forecasts to citizens.

To achieve Pillar 2, technology must be harnessed particularly in terms of improving data quality and access, sharing data worldwide, and enhancing forecasting capabilities. Data collection is often done by satellites and aeroplanes, however, measurements by themselves are insufficient. Data also needs to be collected and shared in real-time to feed the computational forecasting models and to be analysed by the operational centres – with both processes requiring considerable technological capacity. Overall, the goal is to include the risk knowledge with the hydro-meteorological forecasts to move towards impact-based forecasting resulting in risk-informed anticipatory action or response measures.

For data sharing, the WMO Information System is adopted as a powerful technical framework providing data discovery and retrieval capabilities through the Global Information System Centres portals, enabling real-time data exchange between WMO Centres through a network of data exchange systems – the Global Telecommunications System.



In terms of enhancing forecasting capabilities, the WMO focuses on refining the use of predictive tools for significant weather-associated challenges. Leveraging improved data, advanced computational power, and deepening insights into weather and water dynamics are crucial to achieving this goal.
AI is also being considered and utilised to add improved capabilities to the forecaster's toolkit.

EWS allow governments, International Organisations, NGOs, communities, and individuals to prepare and respond to hazardous events faster, giving people crucial time to respond, shelter, and potentially evacuate. This reduces the possibility of injuries and fatalities and mitigates the social and economic damage caused by weather and water-related events.

The WMO’s top decision-making body has accorded that EW4All is the top overriding priority of the organisation, as outlined in the WMO Strategic Plan 2024–2027. Accordingly, key WMO activities and projects are coordinated and consolidated under the EW4All umbrella including the work of the technical commissions and regional activities aligned to achieve the goal. WMO and its partners have several ongoing initiatives and projects worldwide and continue to launch others to support the Member countries with the implementations of EW4All in different regions.

Projects such as Water at the Heart of Climate Action (WHCA), Flash Floods Guidance System (FFGS), Early Warning Systems for floods (EWS-F), and the Climate Risks and Early Warning System (CREWS) initiative continuously support Member countries to strengthen their hydro-meteo early warning services to the population and other stakeholders.

WORLD METEOROLOGICAL ORGANIZATION

Early Warnings for All

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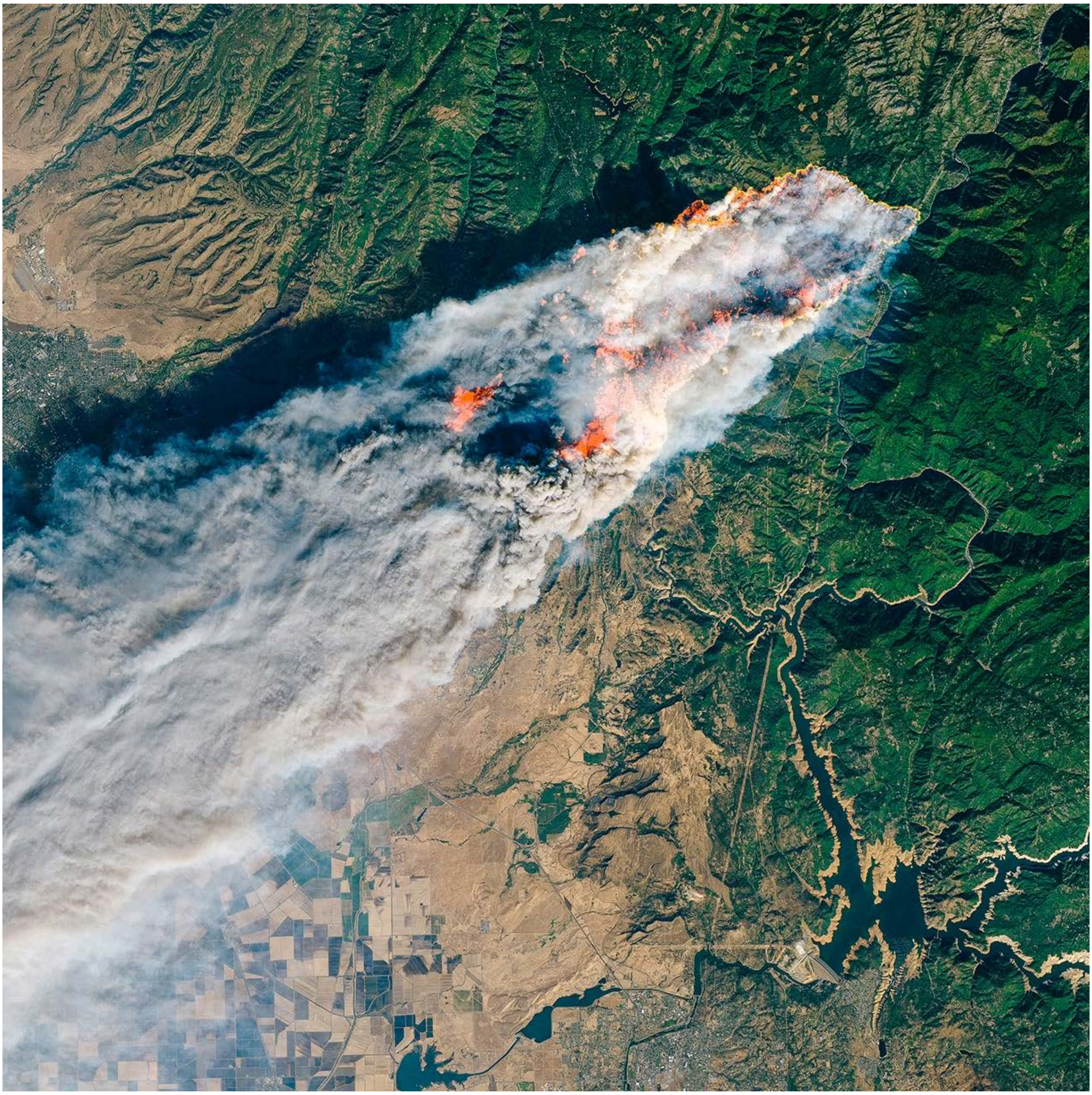
FIRESAT CONSTELLATION

FireSat, Earth Fire Alliance's transformative satellite constellation designed, built, and operated by Muon Space, is set to transform global wildfire detection and response. Launched with the goal of enhancing climate resilience, FireSat provides real-time, high-fidelity data to support more effective wildfire management practices worldwide.

With a goal to enhance climate resilience and to respond to the increasing threat of wildfires fueled by climate change, this project has been developed over five years with the support of leading philanthropies and NGOs, including the Environmental Defense Fund, Google.org, the Gordon and Betty Moore Foundation, and the Minderoo Foundation, with input from over 200 global members of the fire community.



The FireSat Constellation consists of a series of low-earth orbit (LEO) satellites equipped with state-of-the-art multispectral infrared (IR) instruments. These instruments are tailored specifically for wildfire detection with sub-100m average resolution and the ability to identify ignition points as small as 5x5 meters. This capability marks a significant improvement over current satellite technologies, which often are unable to detect fires until they have grown substantially. The ability to monitor wildfires at such an early stage will inform new strategies for fire management and response and empower first responders to take swift action, potentially reducing the devastating effects of uncontrolled fires.

Launching in 2026, FireSat's first three operational satellites will monitor key geographies of wildfire activity on Earth at least twice a day. As the constellation expands to more than 50 satellites, regions at high risk of wildfires will be observed as frequently as every nine minutes, providing near real-time data to the frontline, incident managers, policymakers, and fire-impacted communities. This frequent monitoring allows decision-makers to track fire perimeters, heat intensity, and the rate of spread, all of which are crucial for developing an effective response strategy.

FireSat's multispectral IR sensors are finely tuned to detect key characteristics of fire, enabling accurate assessment of a fire's intensity and stage of development. This high-resolution data, combined with a wide 1,500 km observation swath and an average 80m ground sampling distance, provides unprecedented detail and precision. These technological advancements offer crucial operational data to those on the frontline, improving the safety of people and property and informing new land management strategies to reduce disastrous fires.

FireSat's impact extends beyond emergency response. Its comprehensive data will be made equitably accessible, enabling communities worldwide to integrate wildfire management into their broader climate resilience strategies. The dataset will serve as a valuable resource for Earth Science research, providing a rich historical record of wildfire behaviour. By enabling more accurate fire simulations and models, FireSat can help scientists and policymakers understand the relationship between climate change and wildfire activity. This data-driven approach to wildfire management will also aid in the promotion of beneficial fire practices that reduce fuel loads and contribute to more resilient ecosystems.

Earth Fire Alliance, in partnership with Muon Space, will launch the first FireSat pathfinder satellite in 2025. The initial operational phase of the FireSat Constellation, launching in 2026, will consist of three satellites which will observe every point on Earth at least twice a day. At full capability with 50+ satellites, the revisit times for the majority of the globe improve to 20 minutes. The system will operate in an 'always-on' mode, delivering processed data such as fire detection maps, fire perimeter outlines, and radiative power readings, laying the groundwork for a future in which wildfires are more predictable, less destructive, and better understood.

Earth Fire Alliance Muon Space

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HARNESSING VIRTUAL REALITY TO ADDRESS CLIMATE TIPPING POINTS

The Climate Tipping Points Hub was launched at the World Economic Forum's (WEF) Annual Meeting 2024 by the Global Collaboration Village. The Village is a World Economic Forum initiative, in partnership with Accenture, and powered by Microsoft Mesh. The Hub, a dedicated thematic space within the Village, was created to empower decision-makers to explore the latest climate science and collaborate on robust response pathways. It also reinforces the 1.5°C commitment as a critical physical limit, not just a political target. If this threshold is surpassed, it will likely trigger critical changes to Earth systems that reinforce rather than reduce warming. Each of the Earth system tipping points, of which there are over 25, carries substantial risks for global ecosystems, infrastructure, economies, and societies, yet they are currently underrepresented in mitigation, adaptation and resilience policies.

The Hub is a data-driven, immersive, extended reality (XR) platform that brings decision-makers together to delve into simulations of Earth system tipping points, temperature rise and the associated global risks, as well as solutions and opportunities for their industry, organisation or region. It enhances environmental storytelling, unlocking awareness to promote climate action and translating increased empathy into real-world action. By facilitating these collaborative dialogues, the Hub aims to turn scientific and grassroots knowledge into robust action to build resilience.

Coinciding with the 2024 UN Global Assembly, WEF's annual Sustainable Development Impact Meetings brought together leaders from business, academia, and civil society to explore the Climate Tipping Points Hub. This immersive experience focused on understanding critical climate thresholds, particularly emphasising solutions for the Amazon tipping point. The dialogue comes at a pivotal moment, with high-level biodiversity and G20 dialogues in the region and Brazil's COP30 conference approaching in 2025.

The Village also features the Ocean Hub, where decision-makers explore marine ecosystems and the balance between aquaculture growth and conservation of coral reefs, mangroves, and other critical habitats, especially in sub-Saharan Africa. The Amazon Environment and Energy Experience also address key global challenges: the former uses generative AI, music, and art to highlight rainforest preservation and indigenous culture, while the latter demonstrates how industrial clusters drive energy transitions. Together, these immersive spaces foster diverse voices and impactful collaboration.

> **"As a digital extension of the World Economic Forum, the Village is uniquely positioned as *the* immersive platform for public-private collaboration. We are bringing together diverse voices in our XR environments, like the Climate Tipping Points Hub, and enabling impactful conversations by visualising global issues in unique ways."**

Chieh Huang, President of the Global Collaboration Village

Global Collaboration Village | WORLD ECONOMIC FORUM

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INTERNATIONAL CHARTER ON SPACE AND MAJOR DISASTERS

The International Charter Space and Major Disasters is a collaborative initiative, established in 1999 by the European Space Agency (ESA) and the Centre National d'Études Spatiales (CNES), with the Canadian Space Agency (CSA) joining in 2000. Its primary mission is to provide rapid access to satellite data for disaster management, helping mitigate the impacts of disasters on human life, property, and the environment.

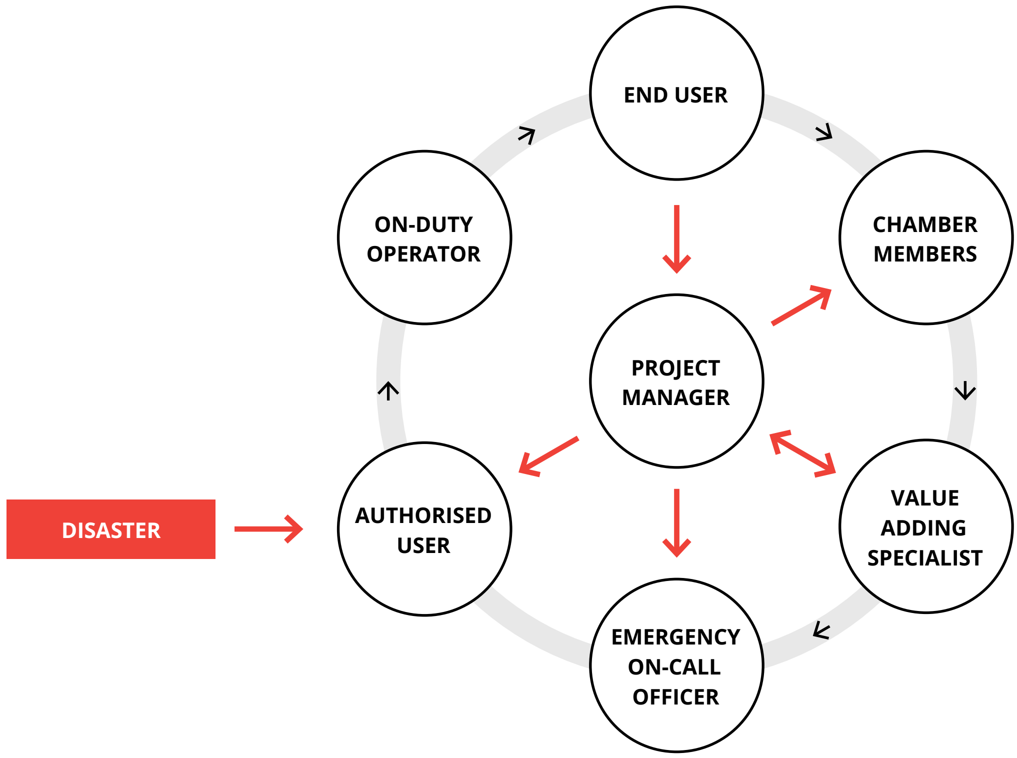
This collaboration now includes a growing number of space agencies from around the world, all contributing their EO resources voluntarily and without any exchange of funds. Some key members include NOAA, the Indian Space Research Organisation (ISRO) and the China National Space Administration (CNSA).

The Charter operates 24/7, offering a single access point for disaster management organisations and civil protection authorities to request satellite data in times of crisis. By leveraging a wide array of satellite sensors, including those that can see in the dark or penetrate cloud cover, the Charter enables comprehensive and timely disaster monitoring, even in the most inaccessible areas.

These resources are used to generate rapid mapping products and damage assessments, which are crucial for guiding relief efforts and decision-making.

The Charter operates on a simple activation mechanism that can be initiated by authorised users, such as national disaster management agencies, UN agencies, and NGOs. The process generally involves the following steps:

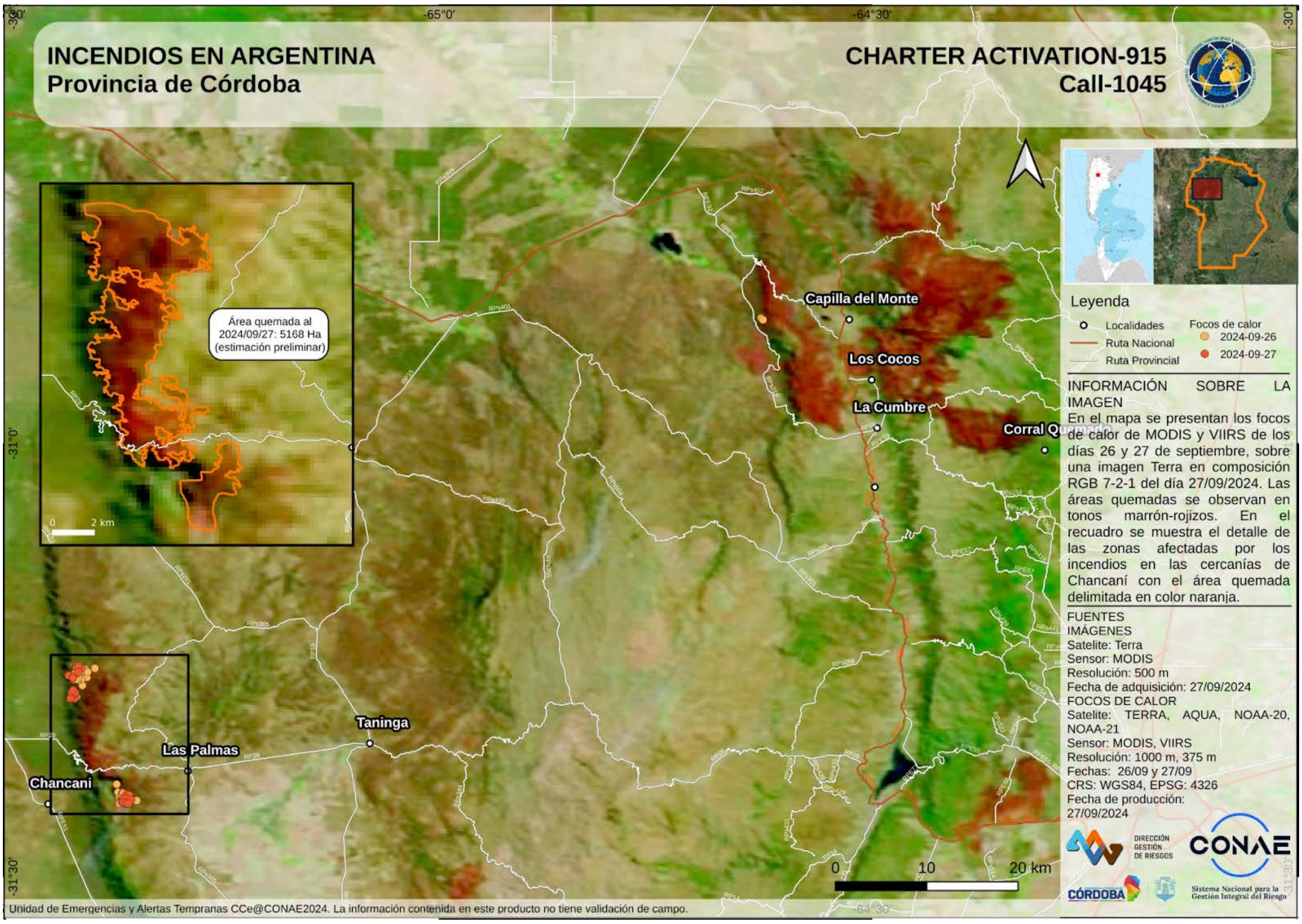
- Activation starts with an Authorised User (AU) submitting a request through the Charter Operational System to mobilise space and ground resources for disaster response.
- A 24-hour On-Duty Operator forwards the request to an Emergency On-Call Officer (ECO) who evaluates the disaster and plans satellite acquisition.
- Relevant space agencies are tasked to gather satellite data based on the ECO's plan.
- A Project Manager is assigned to assist the AU, coordinate data delivery, and oversee the process.
- Value Added Providers interpret satellite data and deliver products like maps for disaster relief to the end user.



RECENT ACTIVATIONS INCLUDE:

- **Hurricane John in Guerrero, Mexico — 28 September 2024**
- **Flood in Sudan — 24 September 2024**
- **Fire in Argentina — 21 September 2024** (see image below)

Areas affected by fires in the Province of Córdoba, Argentina. © NOAA (2024. Map produced by CONAE



While the Charter's core role is the provision of satellite data, member agencies often go beyond this by collaborating with other organisations to offer additional value, such as analysis and interpretation of the data. This enhances the overall response capacity, supporting humanitarian actions and improving resilience in disaster-stricken areas globally.

By facilitating access to satellite data and promoting international cooperation, the Charter enables timely and informed decision-making during crises. As the frequency and intensity of natural disasters continue to rise, the role of such collaborative efforts becomes increasingly vital in saving lives and supporting communities in their recovery.

Project owner
International Charter on Space and Major Disasters

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MOBILISE: A COLLABORATIVE DIGITAL PLATFORM FOR BUILDING RESILIENT COMMUNITIES

The MOBILISE project, initially funded by the Global Challenges Research Funds in the UK and subsequently supported by World Bank grants, focuses on building resilient communities in South Asia, particularly in Sri Lanka, Pakistan, Malaysia and recently in the Maldives. These countries are frequently exposed to natural hazards like floods, earthquakes, landslides, and droughts, which threaten development gains and require a proactive approach to DRM. The project aims to shift the focus from reactive disaster response to a more proactive, risk-aware strategy that prioritises building resilience. Achieving this involves new models of collaboration between government agencies and the use of digital tools that enable stakeholders to plan and respond effectively at the critical early stages of disaster events.

To facilitate this shift, the MOBILISE project has developed an innovative digital platform — MOBILISE 4.0. The MOBILISE platform is a cloud-based decision support system which offers a suite of digital solutions designed to extract actionable intelligence from diverse data sources, including exposure and vulnerability databases, sensor networks, weather forecasting systems, hazard models, crowdsourced information, and satellite imagery. The MOBILISE platform also features secure data-sharing capabilities and interactive visual interfaces and dashboards, facilitating collaboration among stakeholders to establish a comprehensive picture of vulnerabilities across social, economic, and environmental dimensions by exploring 'what-if' scenarios. The intelligence provided by the MOBILISE solutions can aid decision-makers in reducing the impact of climate risks on communities and implementing multi-hazard early warning systems (MHEWS) for anticipatory actions.

The MOBILISE platform presents three modules as follows:

The Multi-agency Risk Assessment Module offers a range of features to help stakeholders better understand their local risks and collaborate to reduce them. Its key features include:

- Secure Multi-agency Data Sharing, which leverages a robust data governance framework and cloud service infrastructure to enable government agencies to securely share critical information, including exposure, vulnerability, and hazards. This feature gives data owners the confidence to share their data in a controlled manner, ensuring that access and usage comply with privacy and security standards.
- Risk Explorer enables stakeholders to establish virtual risk assessment workspaces tailored to specific local risk areas. By utilising built-in scenario generation features, it facilitates collaborative exploration and analysis of risk contexts. By visualising risk information and simulating hazard scenarios, stakeholders can gain valuable insights into the potential impacts of climate hazards on communities, critical infrastructure, and the environment. This insight enables decision-makers to implement adaptive and resilient measures to reduce the impact of hazards on communities.

The Multi-source Real-time Dashboard is designed to help agencies monitor and forecast potential hazards, enhancing situational awareness and providing advance warnings to the community. It leverages data from weather forecast websites and manual and automated monitoring stations for river levels and rainfall, along with community-reported incidents via a mobile app. By offering a comprehensive view of emerging hazard situations, decision-makers can implement pre-emptive measures to minimise the impact of hazards on communities and the environment.

The Community-Centric Early Warning System enables government agencies to digitise their entire early warning authorisation and dissemination workflow, facilitating seamless coordination among national technical agencies, disaster management organisations, local governments, and media outlets. This module's configurable digital workflow ensures targeted early warnings can be sent to the community via SMS, WhatsApp, and a purpose-built mobile app, ensuring vital information reaches a broad audience. The mobile app, an integrated feature of this module, empowers citizens to actively participate in the early warning process by reporting incidents and collecting weather-related data, thereby enhancing the accuracy of hazard predictions by technical agencies.

MOBILISE 4.0 is a vital tool for implementing climate adaptation and resilience strategies, as well as for developing early warning systems and disaster response plans that minimise impact and enhance community resilience. It plays a crucial role in advancing the priorities of the Sendai Framework and supporting the UNDRR and WMO's Early Warning for All initiative.

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SEEDS PROGRAMME: MONITORING SEWAGE FROM SPACE

The Sustainability Exploration Environmental Data Science (SEEDS) programme, a collaboration between CGI and Ordnance Survey (OS), backed by the UN, is advancing efforts to monitor water pollution and detect sewage overspills from space. This initiative harnesses the power of EO and geospatial data to address the growing threat of sewage contamination in rivers, waterways, and coastal regions.

Sewage contamination poses serious risks to public health and the natural environment, disrupting ecosystems and endangering wildlife. In response to these challenges, the SEEDS programme explores how satellite technology can offer a more comprehensive, real-time solution.

As the effects of climate change intensify with increased storm frequency and heavier rainfall, the need for predictive analysis becomes even more critical. Heavy storms often overwhelm sewage systems, triggering overspills that can flood streets, homes, and waterways. The SEEDS programme is developing AI models to predict when and where these overspill events are likely to occur. The best-performing models have already achieved a 91.5% accuracy rate, demonstrating the power of AI in helping authorities and water companies take proactive measures to mitigate the impacts of sewage releases.

CGI and OS are leveraging their combined expertise to identify high-risk areas by using OS location data to analyse land cover types, terrain, and urban density. Urban areas are particularly vulnerable to sewage overspills, as impermeable surfaces like concrete and asphalt prevent water absorption, causing runoff that strains the sewage system. By integrating historical rainfall data from the UK's Met Office, the SEEDS team can better predict where overspills are likely to occur and develop strategies for improving drainage and increasing sewage storage capacity.

Beyond immediate monitoring, the SEEDS programme aims to contribute to global efforts to improve water management and sanitation in vulnerable regions. OS is already using AI and geospatial data to support sanitation infrastructure in developing countries like Zambia, where informal settlements often suffer from inadequate sanitary facilities. These projects underscore the value of predictive analysis in identifying areas most in need of investment in critical infrastructure, helping to create healthier, more resilient environments.

CGI Ordnance Survey

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Satellite imagery in which each pixel translates to 3.7 m^2 on the ground. This could be used to detect organic matter from sewage overspills and their downstream impact.

Image courtesy of Planet Labs PBC.

3. CLOSING REMARKS

The case studies, tools and initiatives included in this report showcase the endless possibilities for incorporating digital technology in each resilience phase to build climate resilience. As climate projections worsen and the impacts of climate change are felt more acutely around the world, it is critical that we adopt the technologies that are available to us to better prepare, respond, recover and adapt to the impacts of the climate crisis.

This report highlights solutions that serve as a blueprint for what is possible when the engineering community collectively problem-solves to create infrastructure that is more resilient, sustainable and inclusive. These examples should serve as inspiration for engineers, scientists, policymakers and communities alike.

However, these emerging technologies are not useful if they cannot be leveraged effectively. Capacity-building efforts are critical to empowering engineers and infrastructure practitioners worldwide with the right skills and abilities to harness available digital technologies. For example, investing in data literacy and digital skills is essential for infrastructure operators to effectively interpret and utilise the data generated by these technologies, thereby improving decision-making processes for infrastructure resilience.

The private sector plays a crucial role in developing and deploying digital solutions for resilience. By leveraging its resources and innovative capacity, the private sector can create scalable and adaptable technologies that meet the diverse needs of infrastructure practitioners. SMEs, like the ones featured in this report, are particularly valuable in this landscape, as they often introduce novel, agile solutions tailored to specific resilience challenges.

In alignment with the Sharm el-Sheikh Adaptation Agenda, incorporating both data and technology into resilience-building initiatives is vital for tracking adaptation progress and adjusting strategies based on emerging insights. While we should be cautious not to rely too heavily on technological advancements to combat climate challenges, these digital solutions foster a culture of informed decision-making that supports global climate agendas. With sustained investment in these areas, we can reimagine a future where infrastructure is smart, responsive, adaptive, and equipped to protect communities and ecosystems despite escalating climate risks.

Savina Carluccio

Executive Director, International Coalition for Sustainable Infrastructure

GLOSSARY

ABM	Agent-Based Modeling
AI	Artificial Intelligence
API	Application Programming Interface
AUD	Australian Dollar
BNG	Biodiversity Net Gain
CBA	Cost-Benefit Analysis
CRED	Centre for Research on the Epidemiology of Disasters
CRM	Cloud Resolving Models
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DTM	Digital Terrain Model
EO	Earth Observation
ESG	Environmental, Social, and Governance
EWS	Early Warning System
FCDO	Foreign, Commonwealth & Development Office (UK)
GHG	Greenhouse Gas
GIS	Geographic Information System
IFRC	International Federation of Red Cross and Red Crescent Societies
IMF	International Monetary Fund
InSAR	Interferometric Synthetic Aperture Radar
IoT	Internet of Things
IR	Infrared
ISRO	Indian Space Research Organisation
Landsat	Land Satellite (a series of Earth-observing satellites)
LiDAR	Light Detection and Ranging
MHEWS	Multi-Hazard Early Warning System
MIT	Massachusetts Institute of Technology
MODIS	Moderate Resolution Imaging Spectroradiometer
NAPs	National Adaptation Plans
NASA	National Aeronautics and Space Administration
NbS	Nature-based Solutions
NCQG	New Collective Quantified Goal
NDCs	Nationally Determined Contributions
NGO	Non-Governmental Organisation
NLP	Natural Language Processing
NOAA	National Oceanic and Atmospheric Administration
NPR	Nepalese Rupee
NWP	Numerical Weather Prediction
OFDA	Office of U.S. Foreign Disaster Assistance

Q-GIS	Quantum Geographic Information System
RDA	Rapid Damage Assessment
ROI	Return on Investment
SAA	Sharm El-Sheikh Adaptation Agenda
SAR	Synthetic Aperture Radar
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goal
Sentinel-2	A satellite mission for Earth observation, part of the Copernicus programme
SME	Small and Medium-sized Enterprise
SMS	Short Message Service
SuDS	Sustainable Drainage Systems
UAS	Uncrewed Aircraft System
UAV	Unmanned Aerial Vehicle
UHI	Urban Heat Island
UN	United Nations
UNDRR	United Nations Office for Disaster Risk Reduction
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations International Children's Emergency Fund
UNITAR	United Nations Institute for Training and Research
UNOPS	United Nations Office for Project Services
UNOSAT	UNITAR’s Operational Satellite Applications Programme
USAID	United States Agency for International Development
USD	United States Dollar
VR	Virtual Reality
WFP	World Food Programme
WMO	World Meteorological Organization
WOfS	Water Observations from Space
XR	Extended Reality

All dollar amounts and references to '$', unless otherwise specified, refer to USD.

International Coalition for Sustainable Infrastructure

www.sustainability-coalition.org