Part A

UNTAPPED

Collective Intelligence for Climate Action

Co-building the Accelerator Labs as a joint venture with:

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UNTAPPED: Collective Intelligence for Climate Action

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The United Nations Development Programme (UNDP) Accelerator Labs is the world's largest and fastest learning network on wicked sustainable development challenges. Co-built as a joint venture with the Federal Ministry for Economic Cooperation and Development of Germany and the Qatar Fund for Development, along with Partners at Core for UNDP, the Italian Ministry of Environment and Energy Security as action partner, and the Japan Cabinet, the Network covers 115 countries, and taps into local innovations to create actionable intelligence and reimagine sustainable development for the 21st century. Learn more at acceleratorlabs.undp.org or follow us at @UNDPAccLabs.

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We use rigorous research methods to test, learn and evaluate each solution. Our flagship Collective Intelligence Design Playbook helped to define the field and is used by practitioners around the world. We have worked with organizations from the UN to the BBC.

To learn more, visit nesta.org.uk/project/centre-collective-intelligence-design or email the team at collective.intelligence@nesta.org.uk

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Authors

Aleks Berditchevskaia, Alex Albert, Kathy Peach, Gina Lucarelli, Alberto Cottica.

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All photos featured in the report were obtained with participants' informed consent.

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Part A

Making the case for collective intelligence in climate

An exploration of the state-of-the-art

What is collective intelligence: data, people, technology

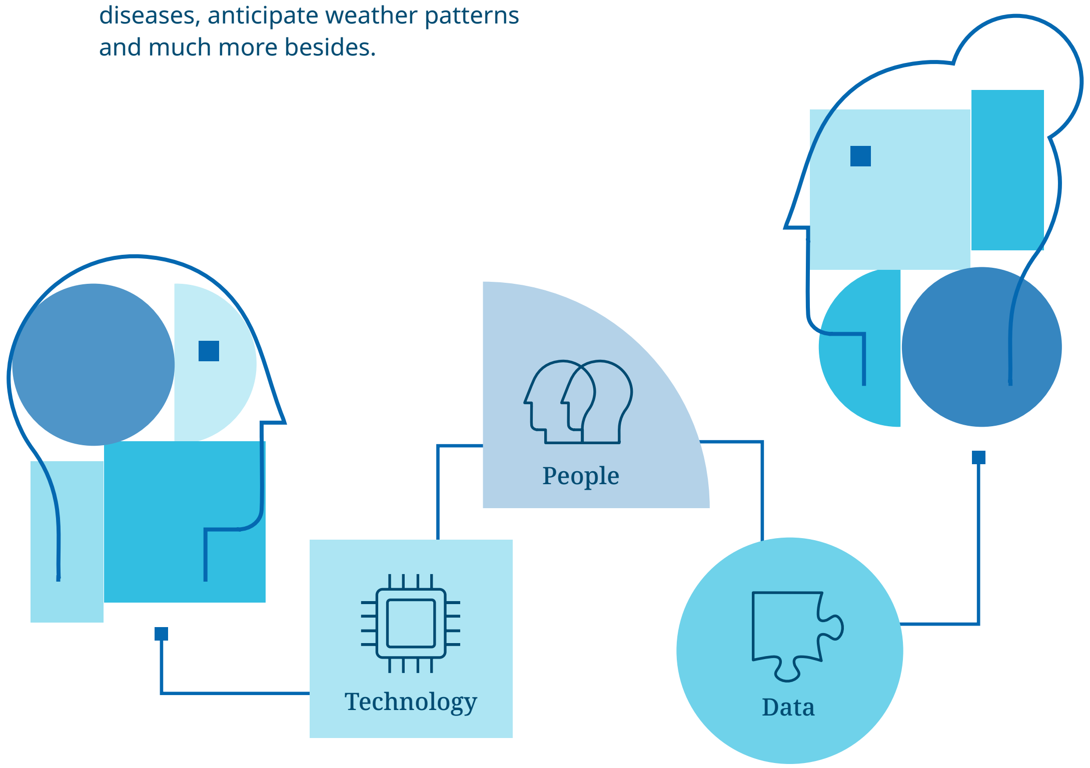
01
It is likely that in the coming years, these tools will become increasingly integrated into collective intelligence initiatives for climate, particularly in the Global North, but this report does not cover AI applications in detail.

At its simplest, “collective intelligence” can be understood as the enhanced capacity that is created when people work together, often with the help of technology, to mobilize a wider range of information, ideas and insights. Collective intelligence (CI) emerges when these contributions are combined to become more than the sum of their parts.

Over centuries, every society has relied on collective intelligence to better understand and adapt to the natural world — sharing knowledge, culture and tools to better manage crops, combat diseases, anticipate weather patterns and much more besides.

Since the start of the digital age, however, the creation of collective intelligence has accelerated in speed and mushroomed in scale. Digital tools now help us to pool ideas in entirely new ways, generate and share new sources of data, and connect people across huge distances. Increasingly, artificial intelligence (AI) is being applied to help make sense from and use large volumes of data, while generative AI techniques are transforming the nature of content and knowledge generation.[01]

The process of collective intelligence design is now one of harnessing both the capabilities and insights of large, diverse groups of people, *and* the power of data and digital technologies to solve problems.



Six use cases for collective intelligence

Published in 2021, Smarter Together: Collective Intelligence for Sustainable Development, was the first attempt to understand how collective intelligence design was being used to address the Sustainable Development Goals. We found six key clusters of use cases — practical ways in which people were using collective intelligence approaches to advance the Sustainable Development Goals.

Although we found collective intelligence work contributing to all aspects of Agenda 2030, the majority of the work we analyzed aligned most closely with targets related to SDGs 10-16, towards equity, responsible governance, sustainable cities and climate action.

Two years hence, further reports from the IPCC have continued to highlight the threat that climate change poses for sustainable development. Extreme weather events put crop production and livelihoods at risk, while climate-related disasters and epidemics ravage property and health. Both resilience to and recovery from these events carry a steep economic cost that will only get worse with a hotter planet. Limiting warming to 1.5 degrees could help achieve sustainable development. A growing literature supports the idea that this could be done while still meeting the needs of everyone on the planet — at least in terms of energy — by reducing overconsumption in the Global North while investing in provision of goods and services to the Global South.[02,03,04]

With *UNTAPPED,* we explore the current and potential contribution of collective intelligence initiatives to more effective climate mitigation and adaptation. Through this analysis we also start to uncover how climate-focused collective intelligence could be designed and implemented most effectively to maximize impact.

02
Creutzig, F., Niamir, L., Bai, X. et al. Demand-side solutions to climate change mitigation consistent with high levels of well-being. Nat. Clim. Chang. 12, 36–46 (2022). https://doi.org/10.1038/s41558-021-01219-y.

03
Joel Millward-Hopkins, Julia K. Steinberger, Narasimha D. Rao, Yannick Oswald, Providing decent living with minimum energy: A global scenario, Global Environmental Change, Volume 65, 2020,102168, ISSN 0959-3780, https://doi.org/10.1016/j.gloenvcha.2020.102168.

04
Jefim Vogel, Julia K. Steinberger, Daniel W. O’Neill, William F. Lamb, Jaya Krishnakumar, Socio-economic conditions for satisfying human needs at low energy use: An international analysis of social provisioning, Global Environmental Change, Volume 69, 2021, 102287, ISSN 0959-3780, https://doi.org/10.1016/j.gloenvcha.2021.102287.

How to read this report

The six collective intelligence use cases identified in our previous work provided our departure point for this report.

We identified over 100 case studies for our core analysis of current collective intelligence initiatives for climate action (see Methodology for detail). This analysis was focused primarily on examples from the Global South to help us understand how collective intelligence could be applied in the places most vulnerable to the impacts of climate change.

Throughout the report, we use the icons corresponding to the six use cases to organize current practice **(Figure 1)**.

We also refer to the IPCC frameworks for mitigation and adaptation options **(Figure 2)** to categorize case studies into groups based on the climate issue being addressed. The analysis in Sections Four and Five is organized by these categories to help practitioners and funders identify the different ways collective intelligence approaches can make a difference on a variety of climate issues, from improved cropland management to ecosystem restoration. Alongside the IPCC framework and the climate action gaps, we refer to a wide variety of collective intelligence methods throughout. A Glossary summarizing the most common approaches can be found at the end of the report.

Section Six offers a forward-looking perspective on where collective intelligence approaches could be applied to accelerate progress on cross-cutting climate challenges, from navigating climate policy decisions to tackling climate-related mis- and disinformation. This section and the second part of the report draw on a broader selection of case studies, including examples from the Global North.

What is a collective intelligence use case for climate action?

A collective intelligence use case is an illustration of a practical way in which people are using collective intelligence methods to take climate action.

Figure 1: Illustrations of the six use cases of collective intelligence applied to climate action

01

New forms of accountability and governance

People participating at scale in climate-related policy processes, feeding into decision making, monitoring implementation or documenting violations.

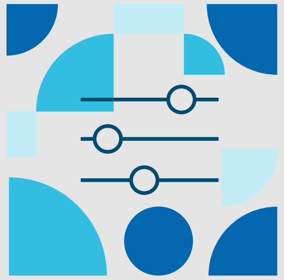
EXAMPLE METHOD AND APPLICATION

A Deliberative Poll® involving members of the public is used to explore different policies for a future energy strategy and make recommendations.

VALUE IN PRACTICE

- Helps policy makers navigate contentious issues and increases the legitimacy of the decision.
- Helps people build consensus on how to tackle difficult/controversial issues where trade-offs might be needed.

02



Anticipating, monitoring and adapting to systemic risks

People working together to prepare for and manage climate-related disasters or epidemics.

EXAMPLE METHOD AND APPLICATION

Citizen science methods are used to involve the public in generating data that helps with disease surveillance or monitoring flooding for early warning systems.

VALUE IN PRACTICE

- The collection of distributed data allows organizations to identify emerging risks earlier and to get a better sense of micro-climate dynamics.
- Creates more timely and local data to help people living in cities reduce risk factors associated with climate-related disease and disasters.

03

Real-time monitoring of the environment

People generating and using data to create evidence for more effective action to address climate change and its impacts.

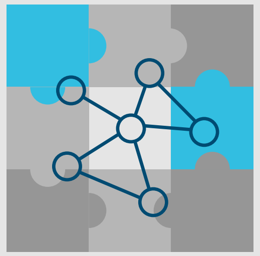
EXAMPLE METHOD AND APPLICATION

Crowdsourcing data to monitor biodiversity and environmental conditions, or ground truth data from satellites, e.g. tree coverage.

VALUE IN PRACTICE

- Gives policy makers an improved ability to identify where, when and what action is needed.
- Creates more timely and local data that builds collective awareness and knowledge about deforestation, changes in farming conditions, violations of protected areas, droughts and floods among other environmental conditions.

04



Understanding and working with complex systems

People developing a shared understanding of natural ecosystems and taking coordinated actions to address climate change.

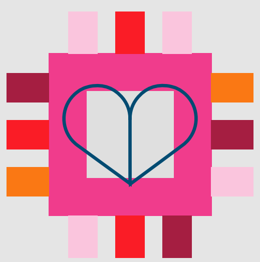
EXAMPLE METHOD AND APPLICATION

Using participatory modeling to support stakeholders to simulate the impact of different interventions to re-store an ecosystem and make decisions together about which actions to take.

VALUE IN PRACTICE

- Enables a group to see “cause” and “effects” of action within ecosystems by mapping out different contributing and interconnected factors.
- Helps different parts of the community to coordinate their contributions to mitigation or adaptation resulting in additive and emergent positive changes.

05



Inclusive development and technologies

People contributing to the design and development of more inclusive climate programmes and technologies.

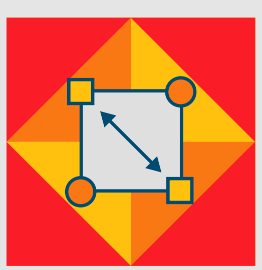
EXAMPLE METHOD AND APPLICATION

Crowdsourcing data from under-represented groups to build more inclusive AI systems that help predict vulnerabilities to extreme weather events.

VALUE IN PRACTICE

- Reduces the potential risks and negative harms of new technologies to target groups.
- Increases the local appropriateness and uptake of new technologies, ensuring they are more accessible.

06



Distributed problem solving

People collaborate to develop, find or implement climate solutions faster.

EXAMPLE METHOD AND APPLICATION

Peer-to-peer crowdsourcing of data, knowledge and ideas for improving agricultural yields in climate-stressed environments.

VALUE IN PRACTICE

Enables the community to utilize existing skills and knowledge to take appropriate action to adapt farming practices to changes in rainfall, soil condition and other agricultural parameters.

Figure 2: IPCC adaptation and mitigation categories

Throughout *UNTAPPED,* we organize the analysis in terms of contributions of collective intelligence to climate adaptation and climate mitigation, using the definitions provided by the Intergovernmental Panel on Climate Change (IPCC). Sections Four and Five provide further detail by grouping case studies into sectoral areas of application drawing on categories from the IPCC’s climate options frameworks.[05]

IPCC Category: Climate Adaptation

Adaptation involves an analysis of the risks caused by climate change and the implementation of measures to reduce these risks. There are currently large gaps between the action taken and what is needed in many regions. Adaptation is essential to reduce harm, but to remain effective, it must go hand-in-hand with mitigation.

Climate response and system adaptation options in this report: improved cropland management, biodiversity management, disaster risk management, and health and health systems adaptation.

IPCC Category: Climate Mitigation

Climate change mitigation is achieved by limiting or preventing greenhouse gas emissions and by enhancing activities that remove these gasses from the atmosphere. Greenhouse gasses can come from a range of sources and climate mitigation can be applied across all sectors and activities.

Climate response and system mitigation options in this report: ecosystem restoration, reforestation, afforestation/reduced conversion of forests and other ecosystems, waste minimization, reduction and management.

05
Adaptation, see: Pörtner, H.O., Roberts, D.C., Adams, H., et al. 2022. Technical Summary: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, TS.C.13.4, 2022. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_TS.pdf. Mitigation, see: IPCC. Working Group III Mitigation of Climate Change. https://www.ipcc.ch/report/ar6/wg3/.

How collective intelligence can close five climate action gaps

Our case study review surfaced examples of practice across a spread of issues and geographies.

Across the wide variety of methods and specific applications observed, there is a common thread about collective intelligence approaches helping to close current gaps in climate action. Below, we introduce these gaps and how collective intelligence initiatives close them, or have the potential to close them, by combining people, data and technology in new ways.

The Data Gap

Closing gaps in environment and climate data.

Despite the progress made by climate science in recent decades, there are still significant *data gaps* that can be a barrier to effective climate action. Notably, SDG indicators for environmental targets lag behind in data collection and compatibility. Policy makers need detailed data on emissions to help transition their energy systems, they need data to assess climate vulnerabilities, and data to understand which adaptation measures are working. Major initiatives, such as the G20's Data Gaps Initiative[06] are starting to tackle the *data gap* — but the environmental and climate monitoring challenge is huge.

Collective intelligence initiatives are playing a key role in helping to fill data gaps by mobilizing citizens to generate real-time localized data, by tapping into community observations to ground-truth findings from surveys and other data, and by bringing together existing data sets to uncover new insights. The use of open data protocols and open data repositories are also enabling the creation of collective intelligence by allowing many different people and institutions to contribute to the creation and use of a shared resource.

06
Bo Li, Bert Kroese. 2022. Bridging data gaps can help tackle the climate crisis: a new data gaps initiative will play an important role in addressing climate-related data deficits. IMF, November 28, 2022. https://www.imf.org/en/Blogs/Articles/2022/11/28/bridging-data-gaps-can-help-tackle-the-climate-crisis. Accessed October 9, 2023.

The Doing Gap

Getting more people involved in solving problems and taking climate action.

The IPCC has made it clear that closing the gap between words and action on climate change is now imperative if climate targets aren't to slip out of reach entirely.[07] The impact of escalating climate-related disasters, from floods in Pakistan[08] to drought in the Horn of Africa,[09] demonstrates how critical it is that action is taken to prevent the loss of lives and property for countries already experiencing devastating impacts of global heating.
.

The scale of "doing" needed in the next few years requires the mobilization of many more people and organizations than at present. Collective intelligence initiatives can help achieve this by enabling people to monitor the actions and follow-through of institutions, industry and government, increasing accountability and transparency of progress in relation to commitments. Digital tools are helping to shift the scale of action by supporting people to take more coordinated and effective actions. Ideas and know-how that are otherwise distributed and difficult to access, are being shared by communities of practice like smallholder farmers or individuals and groups who are dispersed across a region. This means localized actions are scaling to produce additive and emergent effects, helping to transition towards sustainable, climate resilient behaviors at a faster rate.

The Diversity Gap

Closing the diversity gap by bringing a wider range of people and perspectives into climate processes.

Closing the diversity gap in climate action is essential for the sustainable, equitable and just transition of energy systems and action to adapt to climate change.[10] It is often marginalized groups who are most affected by climate change or the introduction of new technologies, yet these same groups are frequently absent from decision-making processes and technology development. As a result, both their needs and priorities often go unrecognized. This exclusion can result in the exacerbation of existing inequalities, less effective policies and technologies, as well as missed opportunities for innovation and locally relevant solutions.

Collective intelligence initiatives are starting to close this gap by deploying more accessible technologies to include historically marginalized communities, like Indigenous Peoples, to bring forward their contribution to the management of natural resources. They often involve people closest to the problem generating new data and validation exercises to address biases in existing climate datasets. Climate innovation challenges that develop new solutions for issues like heat shock in cities or sustainable agriculture, foreground a diversity of contributions and set inclusive eligibility criteria to ensure that new technologies serve more diverse needs.

07
IPCC. 2022. Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/assessment-report/ar6/.

08
UNICEF. 2023. Devastating floods in Pakistan: one year after historic floods devastated Pakistan, UNICEF remains on the ground, working with partners to help children and families. UNICEF.org, August 25, 2023. https://www.unicef.org/emergencies/devastating-floods-pakistan-2022. Accessed October 9, 2023.

09
OCHA. 2023. Horn of Africa drought: regional humanitarian overview & call to action. ReliefWeb, May 26, 2023. https://reliefweb.int/report/ethiopia/horn-africa-drought-regional-humanitarian-overview-call-action-revised-26-may-2023. Accessed October 9, 2023.

10
"Emphases on social justice, equity and different forms of expertise have emerged." See: Pörtner, H.O., Roberts, D.C., Adams, H., et al. 2022. Technical Summary: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 97 TS-5, 2022. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_TS.pdf.

The Distance Gap

Closing the distance between scientific knowledge, lived experience and public understanding.

Addressing the gap between scientific knowledge and public understanding is critical for tackling climate change. Without closing this gap it becomes harder to build public support for the policies that are needed, encourage the collective and timely action that can have the most impact, and resist the influence of mis- and disinformation. Scientists who don't take into account public understanding and experience of climate change at the local level will also lose out on the contextual information that can make scientific models and research more accurate, relevant and tailored to people's needs. Indigenous groups and local communities often possess knowledge about the impact of climate change and their environment that may not be accessible to scientists in other ways.

Collective intelligence initiatives can help close the *distance gap* by fostering a two-way exchange of information between scientists and local communities. The evidence is clear that the process of collecting and analyzing new data together enhances both scientific understanding and the knowledge of the public that participates. Collaborations between scientists and the public through collective intelligence processes also help to promote mutual trust and increase the impact of action to adapt to or mitigate the effects of the climate crisis.

The Decision-making Gap

Closing the gap between viewpoints where trade-offs or complex decisions need to be made.

The more the crisis is felt, the more that taking effective climate action relies on being able to navigate between conflicting viewpoints on a range of issues where different priorities, values and beliefs often arise. Take, for example, agreeing on who should pay for the costs of energy transitions or climate-related damage, what is fair in relation to the impact of policies on different communities, how to balance job creation with green transitions, or how to protect people displaced by climate disasters. The difficulty of closing the gaps between opposing views and interests continues to be a major barrier to the scale and speed of climate action that is needed.

When decision makers listen, collective intelligence initiatives can help to close this *decision-making gap* in a number of ways. For example: by soliciting contributions from a diverse range of people to uncover a wider range of insights for more informed decision making, by promoting the sharing of data and knowledge between people to help build collective understanding of a climate related problem, or by supporting decision-making processes through structured techniques for deliberation.

This report explores how collective intelligence initiatives, enabled by the increasing adoption of digital technologies and/or mobile phones, are helping to address these five gaps across climate adaptation and mitigation.

COLLECTIVE INTELLIGENCE INITIATIVES HELP BRIDGE LOCAL ACTION AND NATIONAL PLANNING.

The value of collective intelligence for climate adaptation

The Global South is particularly vulnerable to the impacts of climate change, and many countries are already experiencing dire consequences such as more frequent flooding, longer droughts and extreme heat. An estimated 3.3 billion people already live in places that are highly vulnerable to climate change — and this is set to grow.[11]

The most successful adaptation initiatives help to reduce vulnerabilities and build community or ecosystem resilience in the face of a warming planet, whilst supporting sustainable development pathways. With the world off track to limit warming to 1.5 degrees, adaptation is increasingly critical.[12]

Our analysis of collective intelligence case studies revealed that most initiatives[13] focused primarily on climate adaptation versus climate mitigation. Given the focus of this report on the Global South which has historically lower emissions, this is not entirely surprising.

We found examples of five collective intelligence use cases:

USE CASE 2
People working together to prepare for and manage climate-related disasters or epidemics

USE CASE 3
People generating and using data to create evidence for more effective action to address climate change and its impacts

USE CASE 4
People developing a shared understanding of natural ecosystems and taking coordinated actions to address climate change

USE CASE 5
People contributing to the design and development of more inclusive climate programmes and technologies

USE CASE 6
People collaborating to develop, find or implement climate solutions faster

11
IPCC. 2022: Summary for Policymakers in Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg2/resources/spm-headline-statements/.

12
United Nations. 2022. Climate change: No 'credible pathway' to 1.5C limit, UNEP warns. UN News, October 27, 2022. https://news.un.org/en/story/2022/10/1129912. Accessed October 9, 2023.

13
71 case studies out of 106.

Addressing *data gaps* is often the main focus of these initiatives, specifically providing measurements about weather, different species and climate-related disasters with geographical granularity and real-time precision. Several examples share these data directly with the people involved, to address frontline *doing gaps.* For example, smallholder farmers with access to better data about weather and/or climate-resilient crop varieties are able to take smarter individual actions. While in cities, sharing data about the real-time spread of extreme weather events like flooding, or the risks that lead to disease outbreaks helps people take coordinated action to reduce the impact of crises. Several initiatives also demonstrate more inclusive technology development, helping to address the *diversity gap.* Digital technology developed together with local communities and Indigenous Peoples, is helping to elevate the adaptation actions taken by these groups and help them to secure funding or influence decisions.

Table 1 provides a summary overview of the four climate adaptation areas where most current collective intelligence practice is concentrated alongside the key methods and climate action gaps that are addressed. These are described in detail in the text that follows.

It is increasingly recognized that adaptation needs to happen at the local level to ensure long-term success,[14] but most adaptation planning so far has been carried out at the national or international level.[15] The collective intelligence initiatives described below are, on paper, one way of bridging local action and national planning.

14
See: Aldunce, P., Blanco, G., et al. 2023. AR6 Synthesis Report: Climate Change 2023. IPCC, March 2023. https://www.ipcc.ch/report/sixth-assessment-report-cycle/ & UNEP. 2022. Adaptation Gap Report 2022. UNEP, November 1, 2022. https://www.unep.org/resources/adaptation-gap-report-2022.

15
Hügel S., Davies A.R. 2020. Public participation, engagement, and climate change adaptation: A review of the research literature. WIREs Clim Change. March 27, 2020. https://doi.org/10.1002/wcc.645.

Table 1:
Summary overview of the existing areas of application of collective intelligence initiatives for adaptation, organized by IPCC adaptation categories

IPCC ADAPTATION CATEGORIES ENABLED BY COLLECTIVE INTELLIGENCE	MAIN COLLECTIVE INTELLIGENCE METHODS BEING USED	MAIN CLIMATE ACTION GAPS BEING ADDRESSED
Improved cropland management	Citizen science and open repositories for climate resilient crops Peer exchange for climate smart agriculture Combining sensor data and citizen-generated data for intelligent networked actions	■ *Data gaps* on local weather or growing conditions ■ *Distance gap* around experiments that happen at small scale and in isolation ■ *Doing gap* around persistence of ineffective farming practices ill-suited to changes in climate ■ *Diversity gap* from failing to tap into and share on-the-ground farmer expertise
Biodiversity management	Participatory sensing for biodiversity monitoring in hard-to-reach locations Citizen science to scale and fast track biodiversity data collection Crowdsourcing Indigenous knowledge to identify rare biodiversity events	■ *Data gaps* about species distribution, ecological interactions and effectiveness of management measures
Disaster risk management	Combining citizen-generated data with official data or sensor data Crowdsourcing data and collaborative modeling to improve scientific models of flood risks	■ *Data gaps* around real-time, localized data about climate-related disasters ■ *Doing gap* from poor coordination and ineffective targeting of resources during disaster response
Health and health systems adaptation	Citizen science for disease surveillance and management Combining citizen-generated data and existing datasets to model disease outbreaks Participatory sensing to measure extreme heat in cities Open innovation for inclusive solutions to extreme heat	■ *Data gaps* on impact of health interventions and on accuracy of modeling ■ *Doing gap* where communities depend on local government for action ■ *Diversity gap* from solutions being provided by a narrow pool of innovators who are removed from the problem

Improved cropland management

Climate change exacerbates land degradation and food insecurity, while land is both a source and sink of CO2. In the Global South smallholder farmers manage approximately 25 percent of farmland and account for close to one-third of the world's food supply.[16] However, smallholders, who are more dependent on rain-fed agriculture, are particularly vulnerable to extreme weather events caused by changes in climate from flash floods to water scarcity occurring as a result of droughts.[17]

Collective intelligence methods are increasingly helping networks of smallholders to adopt climate resilient practices and behaviors. These initiatives help to fill several *data gaps* on local weather or growing conditions. Many farmers are already experimenting with adaptation at a small scale,[18] often in isolation from each other. Collective intelligence approaches, however, enable many farmers to pool knowledge and insights, accelerating their ability to adapt to changes in rainfall, soil quality and other factors and addressing *doing gaps* of ineffective farming practices. Collaborative action by farmers in turn is also creating new scientific data and knowledge that has wider application and use, helping to narrow the *distance gap* about effective adaptation interventions. Together these examples offer a glimpse of how scaled-up, smartly targeted and incentivized actions could enable a larger sector-wide shift in cropland management, while improving the economic prospects of individual farmers.

Citizen science and open repositories for climate resilient crops

One way to build the resilience of smallholders is through the diversification of crops and seed varieties; however, there is a significant *data gap* about how different seed varieties will perform across changing climatic conditions and in different ecological zones. Across South America and Africa, collective intelligence initiatives are addressing this gap through large scale crowdsourcing of data on seed varieties and how well they grow in different local conditions. Popular approaches include citizen science — where volunteers (in this case mostly smallholder farmers) work with scientific researchers to generate new scientific data and knowledge, and the creation of open repositories — digital databases where content (data, code, text or DIY designs) can be stored and freely downloaded or used with few restrictions.

An example of this is the Bioleft platform in South America, which acts as an open-source repository of local seed varieties and facilitates collaborative seed-breeding between farmers to help them identify more climate-resilient options. The platform enables georeferencing of seeds and records their transfer under an official Bioleft license. This system helps to retain the benefits of seeds for local communities through open experimentation, reducing their exploitation by international corporations who take out patents for certain seeds and demand payment for their use.[19]

The platform also supports farmers to build connections and exchange ideas with peers. Seeds for Needs, is another project that helps farmers test which seeds are most appropriate for their local area through a combination of citizen science, large scale field experiments called n-trials[20] and the digital platform ClimMob (see Case Study 1).

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Hannah Ritchie. 2021. Smallholders produce one-third of the world's food, less than half of what many headlines claim. OurWorldInData.org, August 6, 2021. https://ourworldindata.org/smallholder-food-production. Accessed October 9, 2023.

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FAO. 2021. The state of the world's land and water resources for food and agriculture: Systems at breaking point. Synthesis report 2021. https://www.fao.org/3/cb7654en/cb7654en.pdf. Accessed October 9, 2023.

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Sengupta, S. 2023. Meet the climate hackers of Hawaii. New York Times, April 27, 2023. https://www.nytimes.com/2023/04/27/climate/malawi-farmers-agriculture.html. Accessed October 9, 2023.

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Menon, A., Saldanha, L. 2022. Seed activism: patent politics and litigation in the Global South. Environmental Support Group, December 21, 2022. https://esgindia.org/new/campaigns/seed-activism-patent-politics-and-litigation-in-the-global-south/. Accessed October 9, 2023.

20
These refer to experiments taking place outside of lab settings with large numbers of participants. Instead of a few researchers carrying out complicated field trials, large numbers of farmers or gardeners carry out small, simple trials on their land. Taken together, the many small trials can offer valuable information about the local suitability of agricultural technologies.

Peer exchange for climate smart agriculture

Although the concept of climate-smart agriculture has grown in popularity in recent years, its adoption by smallholder farmers faces a number of challenges — including knowledge, finance, technology and infrastructure.

Collective intelligence methods are increasingly helping to bridge *distance* and *doing gaps* — by enabling farmer-to-farmer knowledge exchange. This is an effective way to help farmers fast track improvements to their agricultural practices by sharing and learning from each other. For this reason, mechanisms that support peer exchange are increasingly incorporated into "agri-tech" tools for farmers.

An example of farmer-to-farmer peer exchange is Geofarmer, an open source app that supports farmers in adopting climate-smart applications in Africa and Latin America. Farmers use it to exchange advice about crop, animal and farm management practices. It can also be used by funders and researchers to access location-specific data about the effectiveness of agricultural technologies and practices implemented by farmers in a given region. The Agrolly app provides real-time weather monitoring and crop information to help farmers decide which crops to grow and when. It is another example of a digital tool that enables peer exchange through a social forum where farmers can share advice and solutions using either text or images. So far, it's been tested with smallholders in India, Mongolia and Brazil. In 2022, the team announced that it would open source its annual weather forecasting model under the name OpenTempus to allow others to create new applications.[21]

A pilot project by the NGO Swiss Contact, which worked with smallholders in the Bolivian Andes, also illustrates the value of peer exchange.[22] The project installed low-cost sensor-based weather stations on farmers' land and crowdsourced detailed information about diseases and pests from farmers. It found that crowdsourcing improved weather forecast accuracy by 25 percent and also increased farmers' trust and engagement in early warning systems, meaning they were more likely to take action to prevent pest outbreaks.

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The Linux Foundation. 2022. Two new agricultural technology projects join the Call for Code community at the Linux Foundation. December 7, 2022. https://www.linuxfoundation.org/blog/two-new-agricultural-technology-projects-join-the-call-for-code-community-at-the-linux-foundation. Accessed October 9, 2023.

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Gill I., Steadman I., Peach, K. Collective Intelligence Grants Programme. Nesta. https://media.nesta.org.uk/documents/Collective_Intelligence_Grants_Programme-Experiments_in_collective_intelligence_design_2.0_1.pdf. Accessed October 9, 2023.

Combining sensor data and citizen-generated data for intelligent networked actions

Collective intelligence initiatives help to coordinate the activities of smallholder farmers by triangulating between different data sources — including sensor data and crowdsourced observations. This helps to close *doing gaps* by incentivizing climate-resilient individual and group level behavior through financial rewards.

An important element of these data platforms is the verification of behavior by remote sensing through satellite imagery and/or drones. For example, the BaKhabar Kissan (BKK) app in Pakistan uses satellite imagery and remote soil health sensors to monitor crops and provide personalized recommendations to farmers. The app also helps to close the gaps in the agricultural supply and value chain by providing an online marketplace where farmers can sell directly to consumers.

Open Harvest (nDI Chuma) is a similar system developed by Heifer International. It's an open-source digital platform in the early stages of development[23] that supports agricultural systems in Malawi. Smallholder farmers in Malawi are not always able to maximize their yield or access fair prices for their groundnut crops. Open Harvest visualizes data on farmers' experience and production history and gives customized recommendations on crop management based on climate modeling. The actions taken by farmers are verified by drones and when confirmed, they gain "reputation" credits. These credits allow them to access better deals on loans, helping to reinforce climate-resilient actions for long-term behavior change. Both of these examples use financial incentives and tailored recommendations to influence the actions of individual farmers and amplify adaptive behaviors when aggregated at the regional level.

23
The Linux Foundation. 2022. Two new agricultural technology projects join the Call for Code community at the Linux Foundation. December 7, 2022. https://www.linuxfoundation.org/blog/two-new-agricultural-technology-projects-join-the-call-for-code-community-at-the-linux-foundation. Accessed October 9, 2023.

Case Study 1

Seeds for Needs

GAPS ADDRESSED

Data Gap

Doing Gap

Distance Gap

Decision-making Gap

What is the problem?

Climate change is already affecting food security as extreme weather events, changing patterns of rain and increasing temperatures mean some crops don't grow well and farmers increasingly need to identify appropriate seeds for adaptation. Organizing large scale field trials (known as n-trials) that generate evidence about the efficacy of new crop varieties and fertilizers is a costly, resource and time intensive process.

What is the collective intelligence solution?

Seeds for Needs is an initiative that works with smallholder farmers to identify the most climate resistant seeds for their local areas using citizen science. Farmers plant different varieties of seeds on their own farms and evaluate which ones grow best. Farmers report back their observations on their phones, using a free, open source software called Open Data Kit. The data from the farmers is aggregated and analyzed on the ClimMob platform, a free software that supports the design of large scale agricultural citizen science. Farmers access the platform to get the information about which seeds perform best in local conditions.

What was the benefit of using collective intelligence for this issue?

The combined knowledge that the farmers have generated has been proven to find seeds that are much better at surviving extreme weather conditions than those recommended on official government lists. To date, Seeds for Needs has engaged more than 50,000 citizen scientist farmers from 14 countries across Africa, Asia and Central America. Researchers have applied the methodology to help smallholders in Central America identify bean varieties that were most suitable under conditions of drought and water scarcity. Another example is a project in Nicaragua where field tests with seeds from the national seed bank help local farmers, many of whom are women, learn about crop-breeding techniques and how to adapt them to changes in the environment.[24]

What does this experience tell us about collective intelligence and climate action?

Instead of a few researchers carrying out complicated field trials, large numbers of farmers or gardeners carry out small, simple trials on their land. Taken together, the many small trials can offer valuable information about the local suitability of agricultural technologies. The rapid analysis of results through the ClimMob software means that farmers get quick feedback about the efficacy of different crop varieties which means they can make timely decisions about which crops to grow the following season, resulting in overall improved cropland management. The ClimMob software design enhances accessibility via design features such as a simple ranking-based feedback format that allows even farmers with low literacy skills to contribute their evaluation data through various channels, including mobile telephones.[25]

COLLECTIVE INTELLIGENCE USE CASE
Distributed problem solving

IPCC CATEGORY
Adaptation, Land and ocean ecosystems, Improved cropland management

COUNTRIES
Multiple — 14 countries across Africa, Asia, and Central and South America

COLLECTIVE INTELLIGENCE METHOD
Citizen science

PEOPLE
Local farmers, scientists

DATA
Environmental samples, citizen-generated data

TECHNOLOGY
Open Data Kit (ODK) app, ClimMob data platform

24
CGIAR. Seeds for Needs: citizen science and crowdsourcing. (Website). https://www.cgiar.org/innovations/seeds-for-needs-citizen-science-and-crowdsourcing/. Accessed October 9, 2023.

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van Etten, J., de Sousa, K, et al. 2019. Crop variety management for climate adaptation supported by citizen science. PNAS, February 19, 2023. https://www.pnas.org/doi/full/10.1073/pnas.1813720116.

Biodiversity management

Climate change has caused local species loss and increased mass mortality for plants and animals, resulting in climate-driven extinctions and declines in the key benefits provided by nature, from clean air and water to raw materials for goods.[26] Monitoring biodiversity is critical for effective conservation management, as well as effective climate mitigation and adaptation action. This is not restricted to the terrestrial environment but also affects marine and freshwater ecosystems.[27] Biodiversity helps to buffer against the impacts of climate change — such as floods, droughts and food insecurity. The ambitious targets of the 30 x 30 landmark agreement reached by the UN Convention on Biological Diversity in December 2022 to protect at least 30 percent of land and sea for nature by 2030, have brought the critical focus on biodiversity management into even sharper focus.

At present, effective biodiversity management is hindered by large gaps in data about biodiversity — from the distribution of species, to their ecological interactions and the effectiveness of different management measures. The *data gap* is made more challenging by the scale and complexity of the task. Identifying and classifying species accurately can be difficult — and some species remain poorly known (particularly in less studied parts of the world). Alongside this, biodiversity data is needed both at fine-grained local scales and at the global scale — and over longer periods of time. Yet the resources to carry out this level of monitoring evades most scientific researchers or governments. The lack of data can play into a lack of political will by decision makers, making it easier to prioritize short-term economic opportunities above biodiversity targets and undermining aspirations for evidence-based decision making.

Collective intelligence initiatives are increasingly helping to address these data gaps by mobilizing community members, Indigenous populations and volunteers to collect and analyze species data using citizen science and crowdsourcing. In some examples, citizen-generated data on species biodiversity is paired with other sources of data, such as satellite data to help adjust or build globally relevant scientific models. As well as helping to create scientific knowledge, collective intelligence projects that involve members of the public also close the *distance gap* — helping communities to build awareness and knowledge of their surrounding environment and how it is being changed due to climate pressures. For this reason, many citizen science biodiversity monitoring projects include an explicit educational objective built into their design.

Participatory sensing for biodiversity monitoring in hard-to-reach locations

Improving knowledge about species distribution in hard-to-reach locations like rainforests and oceans is a pivotal benefit of collective intelligence biodiversity projects. A key method being used in this type of project is participatory sensing which involves groups of people using and collecting information from digital sensors and recording physical changes or conditions in the environment. Sensors can increasingly provide cheap, real-time measures of a wide range of different biodiversity data.

An example of this is Rainforest Connection's Arbimon platform which has been used in Puerto Rico to conduct island-wide surveys using passive acoustic monitoring (PAM) with in-situ sensors. The acoustic sensors are created using old mobile phones crowdsourced from volunteers, who are also involved in generating biodiversity monitoring data. The platform uses machine learning to identify matching samples and to compare biodiversity monitoring in different locations. These tools have been applied to collect data from 841 sites across the archipelago during the three-month peak of bird breeding season.[28] The large sampling area and the volume of data would be impossible for researchers to gather on their own. The data is used to implement eco-acoustic and conservation monitoring systems including for anti-logging and anti-poaching initiatives, and to drive conservation action by wildlife managers on the ground.

The Secchi app is a citizen science project that estimates phytoplankton biomass from data about ocean transparency. Phytoplankton are microscopic marine algae that underpin the marine food chain and climate change has driven species decline. Researchers' ability to collect data and understand this effect has lessened over recent years due to the scale and challenging conditions of the ocean which can make it hard to take in-situ measurements. The global Secchi Disk study engages seafarers to fill this *data gap* using low-cost DIY sensors called Secchi Disks. Seafarers lower the sensor into the water (following a standardized data collection protocol) to obtain readings about water transparency. The aggregated data from the readings can be downloaded by scientists from the project website, where the data is also visualized on a map. In addition to raising awareness about marine ecology to bridge a *distance gap,* this project is helping to fill a vital *data gap* for researchers working on marine ecology.

Citizen science to scale and fast track biodiversity data collection

Global environmental monitoring projects are helping to fast track data collection on key biodiversity indicators, creating observation datasets at a scale previously unimaginable for ecologists. Citizen science is already a well-established collective intelligence method for biodiversity data collection in the Global North, but its use is expanding in Global South contexts. It has huge potential to fill *data gaps* more quickly, cheaply and at much greater scale than can be achieved by scientists working alone. Citizen science initiatives often standardize protocols for data collection and measurement, and use simple tools to enable volunteers to easily contribute to effective environmental monitoring.

For example, through Seagrass-Watch, the global seagrass observation program, citizen scientists have conducted over 5,700 assessments at 418 sites across 26 countries since 1998. The programme has a strong emphasis

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UNEP. 2020. UNEP and Biodiversity. September 2020. https://www.unep.org/unep-and-biodiversity. Accessed October 9, 2023.

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Ford, J., Cameron, L., Rubis, J. et al. Including indigenous knowledge and experience in IPCC assessment reports. Nature Clim Change 6, 349–353 (2016). https://www.nature.com/articles/nclimate2954. Accessed October 9, 2023.

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UNEP. 2022. What you need to know about the COP27 Loss and Damage Fund. November 29, 2022. https://www.unep.org/news-and-stories/story/what-you-need-know-about-cop27-loss-and-damage-fund. Accessed October 9, 2023.

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Germanwatch. Global Climate Risk Index 2021. ReliefWeb, January 25, 2021. https://reliefweb.int/report/world/global-climate-risk-index-2021. Accessed October 9, 2023.

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Rentschler, J., Salhab, M. 2020. People in harm's way: flood exposure and poverty in 189 countries. World Bank Climate Change Group and the Global Facility for Disaster Reduction and Recovery, October 2020. https://openknowledge.worldbank.org/server/api/core/bitstreams/e218989e-8b3b-5f8c-944c-06e9812215aa/content. Accessed October 9, 2023.

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UNEP. 2021. UN issues new guidance to address warming in cities. UNEP Press Release, November 3, 202. https://www.unep.org/news-and-stories/press-release/un-issues-new-guidance-address-warming-cities. Accessed October 9, 2023.

on consistent data collection, recording and reporting. Seagrass-Watch identifies areas important for seagrass species diversity and conservation, and the information collected is used to assist the management of coastal environments to prevent significant species loss. The hands-on and participatory nature of Seagrass-Watch is at once a cost-effective method of collecting data and helps to build local interest and ownership in management of coastal seagrasses, bridging a key *distance gap*. The project has generated local support for marine conservation and built closer relationships and partnership networks between community groups and local government for efficient seagrass conservation and management.

The GLOBE observer programme, NASA's largest and longest-lasting citizen science program about Earth, crowdsources observations of Land Cover and Trees with planned expansion to other types of data in the future. Crowdsourcing citizens' tree observations and measurements of tree height (and optionally tree circumference) with GLOBE Trees, allows for the tracking of tree growth over time. Tree height is the most widely used indicator of an environment's ability to grow trees, and can inform understanding of the gain or loss of biomass. NASA regularly organizes global data collection challenges through the GLOBE programme — these are short, focused periods of data collection that help to generate a lot of data quickly. In 2022, their month-long Trees Challenge helped to generate a dataset of more than 4,700 observations in over 1,500 locations worldwide. This citizen-generated data is used to ground truth satellite observations and contributes to the development of more accurate scientific models of tree coverage, carbon emissions and carbon sequestration.

Crowdsourcing Indigenous knowledge to identify rare biodiversity events

Indigenous communities build up specialized knowledge about local biodiversity over generations, making them well placed to identify unusual or rare signals of climate-related changes to local ecology. However, Indigenous or local knowledge has typically been underrepresented in scientific research and IPCC reports.[29] But it is increasingly acknowledged that the inclusion of Indigenous populations in biodiversity management will enhance the local relevance, appropriateness and sustainability of these interventions. Although significant challenges exist, there are examples of collective intelligence projects that have worked effectively with Indigenous groups to help address the biodiversity *data gap* and the *diversity gap* in climate action. In particular, collective intelligence initiatives that work with Indigenous communities tend to make use of their historic and longitudinal knowledge of their local environment to generate data on new or rare events. CyberTracker Kalahari is a platform that scales this expertise and replicates biodiversity field projects in the Kalahari Desert in Southern Africa. The project employs Indigenous trackers to contribute to large-scale, long-term monitoring of biodiversity, ecosystems and landscapes for conservation management using a simple app. The CyberTracker software, which is free, is contributing to environmental conservation worldwide, not just by trackers, but for scientific research, conservation management and anti-poaching — it has been downloaded more than 500,000 times. Similarly, the Local Environmental Observer (LEO) Network of local Indigenous observers crowdsources examples of unusual animal, environment and weather events in the Arctic.

Disaster risk management

Extreme weather events such as floods, earthquakes and fires are increasing in frequency and they compound other crises like food and water insecurity. The impacts from extreme weather events hit the poorest countries hardest as these are particularly vulnerable to damage caused by environmental hazards and may need more time to rebuild and recover.[30] Between 2000 and 2019 over 475,000 people lost their lives as a direct result of extreme weather events globally.[31] Floods are one of the most common climate-related hazards and an estimated 1.47 billion people globally are exposed to flooding's substantial risks.[32] But extreme heat is a growing threat, particularly in cities, and current climate trajectories will mean at least twice as many megacities could become heat stressed, exposing more than 350 million people to deadly heat by 2050.[33] Mitigating and responding to climate-related disasters poses a number of challenges due to their complexity and the fact that the needs of crisis-affected communities outstrip available humanitarian resources.

Collective intelligence initiatives are attempting to tackle this problem in two main ways. The first is by addressing several *data gaps*. Early warning systems and enhanced emergency preparedness and response are critical to reducing loss and damage from climate disasters, but both require good quality, localized data to ensure relevant and effective targeting of resources. Crowdsourcing is creating localized data on hazards, which, in combination with other sources including official data or sensor data, helps improve the precision of local forecasts, early warning systems and risk models. In some examples, collective intelligence goes beyond addressing the *data gap* to target *doing gaps* — enabling both frontline responders and affected communities to take more coordinated and effective action during a crisis. They do this by sharing hazard or vulnerability data with communities to raise awareness and build capacity, or by providing enhanced situational awareness and early warning alerts to officials through digital dashboards.

Citizen-generated data (in combination with other data) for early warning, preparedness and response to disasters

The UN Secretary General's Early Warnings for All initiative has focused international attention on the importance of investing in early warning systems, which can help to dramatically reduce large financial losses from climate disasters.[34] But to generate the forecasts needed to ensure everyone is protected by early warning systems by 2027 it is necessary to address several gaps in weather observation.

Collective intelligence methods such as crowdmapping and crowdsourcing are currently filling some of these *data gaps* on climate hazards, infrastructure and weather — expanding the range of available data sources that can be used to provide early warnings and situational awareness of a crisis. An example of this is PhilAWARE, a hazard monitoring and early warning system to improve disaster management and decision making in the Philippines. It was built using local infrastructure data mapped with local and global volunteers through Humanitarian OpenStreetMap. It consolidates hazard information and alerts from various sources and disseminates alerts to officials and impacted communities to help them take action.

Similarly, in Uruguay, the Monitor Integral de Riesgos y Afectaciones (MIRA), is an integrated disaster management and early warning system that combines several official and citizen-generated datasets. It gathers social media data and crowdsourced reports[35] about the impacts of disasters on homes, goods and services for improved situational awareness, and issues text alerts directly to affected communities.

Community Water Watch is a community designed and operated early warning service focusing on flooding in Dar es Salaam, where floods are a constant threat and often result in fatalities. The service collects information about real-time flooding by web-scraping online news and crowdsourcing reports from affected people via a chatbot on the messaging app Telegram. It combines these data with hydrometeorological data collected through low-cost sensors to provide situational reports about the precise location of floods. These are shared with frontline responders at the Tanzanian Red Cross and their volunteers so they can respond more quickly and target their support to where it is most needed.

The Living Lab of West Africa takes a different approach to flood management in Ouagadougou, Burkina Faso, a city that's been affected by increasingly frequent and intense flash floods. The project used crowdmapping to identify waste dumping sites that were blocking drains and installed low-cost rain gauges to collect water level data in strategic locations across the city. Combining these datasets and official data, they plan to build a forecasting model to provide early warnings to responders and local residents. The initiative has brought together residents, government officials and municipal services to collaborate on more effective responses to flooding. The Lab also organizes skills and capacity building sessions where residents learn new approaches to land rehabilitation and composting, and participate in waste cleanup to reduce the impact of flash floods. These activities raise awareness about the links between personal behaviors, climate change and local impacts.

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World Meteorological Organization (WMO). Early warnings for all. https://public.wmo.int/en/earlywarningsforall. Accessed October 9, 2023.

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UNDP. 2019. MIRA: innovative platform for comprehensive risk management in Uruguay. UNDP, October 10, 2019. https://www.undp.org/es/uruguay/news/mira-innovadora-plataforma-para-la-gesti%C3%B3n-integral-de-riesgos-en-uruguay. Accessed October 9, 2023.

Crowdsourcing data and collaborative modeling to improve scientific models of flood risks

Collective intelligence initiatives are also creating novel datasets about flooding — unprecedented in scale and granularity — through crowdsourcing of videos and localized knowledge. This improves the ability of scientists to develop accurate, high resolution flooding models to understand the risks posed by flash floods.

Floodchasers is a project that crowdsources videos of flash floods into a centralized database for hydrology researchers. It was created due to the insufficiency of information on flash floods in urban rivers and basins. Videos are submitted by members of the public and responders at the frontlines of flooding events. This dataset is helping scientists better understand river behaviors and flooding patterns, and improving the calibration of water flow models that are used to create forecasts and warnings.

Another example is an initiative run by Deltares in Tanzania[36] with the Tanzania Red Cross Society, the World Resources Institute and others. They work with local residents to map and label infrastructure in flood-prone areas of Dar Es Salaam using OpenStreetMap. Residents draw on their local knowledge to add detail about buildings and their elevation, creating a high quality hazard dataset of the area. Researchers have used this dataset and causal information gathered during collaborative modeling workshops with participants to develop a flood risk model with street level precision, a higher resolution than is normally possible.

36
Naffaa. S. 2018. Participatory terrain data and modelling in Tanzania. Deltares, February 6, 2018. https://publicwiki.deltares.nl/display/CM/Participatory+terrain+data+and+modelling+in+Tanzania. Accessed October 9, 2023.

Health and health systems adaptation

Rising temperatures and increased precipitation can promote an array of infectious diseases, from vector-borne diseases (such as malaria and dengue), to intestinal infections and diarrhea (such as cholera). Mosquitoes in particular do better in warmer climates, and if current trends continue, an estimated 6.1 to 8.4 billion people will be at risk from malaria and dengue by the end of the century, primarily in the GlobalSouth.[37,38] Another significant threat to health is the increasing frequency and intensity of heat-related disasters such as heatwaves, droughts and wildfires.[39] Urban heat islands,[40] mean that extreme heat events are felt even more profoundly in cities, putting the health of urban populations at risk, disproportionately impacting the poorest communities.[41] Urban heat exposure is on the rise and it's estimated that the world's hottest cities will experience heat levels adverse to human health for up to half of the year by 2050.

As the scale, location and nature of these health risks change, it will be important for data collection to keep pace so that impacts on health and health systems can be understood and interventions properly targeted and designed. Collective intelligence initiatives are helping to close these *data gaps* — by involving communities in monitoring factors that contribute to the spread of climate-related diseases such as mosquito breeding grounds. These efforts often help close the distance between scientific knowledge and public knowledge — creating more locally relevant science and more informed communities. A smaller number of collective intelligence initiatives pair data collection activities with microtasking — using the data generated by communities and heightened community awareness to direct and incentivize activities, such as destroying mosquito breeding grounds. Collective intelligence solutions like this can empower people to use data themselves to prevent the spread of the disease, rather than looking solely towards local governments alone to solve problems. Involving more people in tackling problems themselves is one key way collective intelligence initiatives can help to close the *doing gap*.

Finding and adopting health solutions that are scalable, locally appropriate and inclusive is also important to tackle the impacts of climate-related health challenges as they start to affect more people globally. Collective intelligence methods, such as crowdsourced open innovation and challenge prizes, are meeting this need by attracting new innovators to work on solutions for urban heat, including those with experience of the issue. The best examples of open innovation set contextual constraints that solutions have to satisfy so they better serve the needs of vulnerable communities. These approaches help to address the *diversity gap* in climate action — by bringing in diverse voices to find solutions.

Citizen science for disease surveillance and management

Mosquitos are the most prevalent vectors of infectious disease. Involving local communities in collecting data about mosquitoes for disease surveillance can enhance the work done by health officials who have typically carried out such tasks — and empower communities to take action themselves.

In Colombia, the Premise tool has been used to support data collection to help prevent Zika outbreaks across three cities: Cali, Cucuta and Sanata Maria. During a pilot phase in 2018, more than 7,000 local volunteers were trained to inspect drains, gardens and other locations for mosquito breeding sites. They submitted their reports and photos on the Premise app using their phones. This data was then verified, aggregated and shared with public health officials so they could intervene before an outbreak occurred. The tasks were co-designed with local health authorities from the outset to ensure that the data could be used by decision makers. The volunteer network ultimately carried out over 108,000 home inspections. They were also trained in how to destroy breeding grounds around their own homes and take steps to keep them mosquito-free. As a result of this citizen-led surveillance and official response there was a 65 percent reduction in breeding sites in the areas that received regular inspections.[42]

DengueChat is a similar Latin American project that uses citizen science to control disease outbreaks at a hyperlocal level. Like the Premise example, it also uses a digital platform to enable community data collection about mosquito breeding sites. The site also has a community portal where residents learn about disease spread by mosquitoes and effective control measures (See Case Study 2).

Combining citizen-generated data and existing datasets to model disease outbreaks

Disease modeling enables public health officials and researchers to make predictions about the size, duration and geographical spread of an outbreak. Models are widely used to identify high risk areas, design interventions, set public policy and direct resourcing. However, at the start of new outbreaks or when new diseases emerge there is often a *data gap* that can make models less accurate. Collective intelligence methods such as citizen science and crowdsourcing are an effective way to fill these *data gaps* by mobilizing communities to collect disease outbreak data themselves.

The Water-Associated infectious Diseases in India: digital Management tools (WADIM) project[43] is a rare example of disease surveillance for waterborne diseases. It's an early stage initiative led by Plymouth University and research partners in India. It aims to map community vulnerability and incidence of cholera by crowdsourcing data about sanitary conditions and symptoms of waterborne diseases using a smartphone app. Sanitation surveys are used to validate the citizen-science-based risk maps, and there is a training and stakeholder engagement programme to introduce the app to local residents. In the future, the data will be combined with satellite data about floods and community surveys to improve cholera risk modeling and to build resilience in affected communities.

A more established initiative operating at the global level is the GLOBE Mosquito Habitat Mapper, which asks citizen scientists to record breeding sites and identify the species of mosquito being observed. These observations make it possible to track the range and spread

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Colón-González, F.J., Sewe, M.O., et al. 2021. Projecting the risk of mosquito-borne diseases in a warmer and more populated world: a multi-model, multi-scenario intercomparison modelling study. The Lancet, vol. 5 no. 7, July 2021. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(21)00132-7/fulltext.

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An urban heat island (UHI) is an urban area that is significantly warmer than its surrounding rural areas due to human activities.

41
Li, D., Bou-Zeid, E. 2013. Synergistic interactions between urban heat islands and heat waves: the impact in cities is larger than the sum of its parts. Journal of Applied Meteorology and Climatology, 52(9), 2051-2064. https://doi.org/10.1175/JAMC-D-13-02.1.

42
Premise. 2020. Zika Grand Challenge project success: using data and digital technology for vector control. https://www.premise.com/wp-content/uploads/2020/03/Premise_Case_Study_Zika_Virus_Success.pdf. Accessed October 9, 2023.

43
Plymouth Marine Laboratory. 2023. Using community knowledge and citizen science to help tackle climate-sensitive, water-associated infectious disease. February 6, 2023. https://www.pml.ac.uk/News/Using-community-knowledge-and-citizen-science-to-h. Accessed October 9, 2023.

of invasive mosquitoes worldwide. Since 2017, more than 32,000 Mosquito Habitat Mapper observations have been submitted by citizen scientists in 84 countries.[44] All data reported by citizen scientists are publicly available. Scientists are using this data to develop new models about the spread of disease and to recognize larvae and mosquito breeding sites from digital images.

Another example which combines crowdsourced data with other datasets for disease modeling is the Epidemic Prognosis Incorporating Disease and Environmental Monitoring for Integrated Assessment (EPIDEMIA). This is an open source model which supports malaria forecasting in epidemic-prone regions of Ethiopia. EPIDEMIA uses machine-learning methods with malaria surveillance data and environmental data from Earth-observing satellites to determine the relationships between climate variations and malaria outbreaks.

Participatory sensing to measure extreme heat in cities

The use of low cost sensors by communities and groups of volunteers enables the collection of new data on emerging climate health risks including extreme heat. Although data on surface temperature can be monitored remotely by satellites, it often lacks the fine-grained resolution necessary to understand hyper-local variations — or to measure the impact indoors or on people themselves. This is where collective intelligence initiatives can fill an important *data gap*.

Urban Heat Islands is a field campaign started by the US National Oceanic and Atmospheric Administration (NOAA) to raise awareness about the many impacts of extreme heat and the factors that may affect the uneven distribution of heat throughout a community. They use low-cost sensors and in-person data collection campaigns to engage volunteers in monitoring how extreme heat is distributed in their neighborhoods. The data on air temperature and humidity are used to create a Heat Vulnerability data dashboard and to design hyper-local contextually appropriate adaptation measures, with the involvement of local residents. In the past, it has been used to develop urban heat action plans and decide on the best placement for resilience hubs to support communities during power outages.[45] Originally developed for implementation in US cities, the method also transferred to Sierra Leone and Brazil in 2023.

44
Low, R. D., Schwerin, T. D., et al. 2022. Building International Capacity for Citizen Scientist Engagement in Mosquito Surveillance and Mitigation: The GLOBE Program's GLOBE Observer Mosquito Habitat Mapper. Insects Vol. 13, no. 7: 624, July 13, 2022. https://www.mdpi.com/2075-4450/13/7/624. Accessed October 9, 2023.

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Poon, Linda. 2022. It takes a village to map the urban heat island effect. Bloomberg, November 28, 2022. https://www.bloomberg.com/news/articles/2022-11-28/citizen-scientists-map-urban-heat-down-to-the-block-level. Accessed October 9, 2023.

Similarly, the VITO project[46] works with local volunteers to map heat stress at a street-by-street level using low-cost sensors. The project started in Johannesburg where 100 local volunteers created a detailed map of six neighborhoods and has also been implemented in the city of Ekurhuleni, South Africa.[47] They aimed to gain more insight into the impact of different factors of spatial elements such as buildings, shade and vegetation on urban heat. The resulting maps were used to demonstrate the disparities between rich, residential neighborhoods and poor townships and shared with local politicians, who are using the data to develop tailored adaptation interventions. In several townships, residents have urged the local government to plant more trees in their neighborhoods and to teach children about global warming and its consequences in school. The same approach was implemented in Niamey, Niger, in March 2023, to map heat stress at the resolution of individual houses and trees. The results will be used to develop an urban climate model which aims to predict the impact of green infrastructure on heat stress.[48]

A less-frequently used technology for measuring the impact of heat stress on urban residents are wearables. This approach has mostly been implemented in Global North contexts[49] where the technology is already relatively widespread, but recently, pilot studies in Kenya and Burkina Faso have looked to test their feasibility in low-resource settings.[50]

Open innovation for inclusive solutions to extreme heat

Collective intelligence methods such as open innovation competitions and challenge prizes can help generate a wider range of solutions, helping to close the *diversity gap*.[51] They can influence the trajectory of technological development to be more responsible, for example, through setting assessment criteria based on maximizing inclusion and by engaging a wider pool of problem-solvers.

The Global Cooling Prize is a global challenge prize competition to spur the development of more energy-efficient cooling technology. The prize was designed to incentivize the development of an affordable residential cooling technology that would have at least five times less climate impact than current solutions. It attracted applications from 31 countries, and the two winning entries were proposed by teams from China and India who had firsthand experience of the issue. The Global Cooling Prize supported the initial development of inclusive cooling technologies but broader adoption and scaling will require further market incentives through collaboration between innovators, manufacturers, investors and policymakers. A similar initiative, the Million Cool Roofs Challenge, aimed to develop inclusive solutions to improve cooling options for vulnerable communities without economic means to access mechanical cooling during heat stress events. Most finalists were based in Global South countries, with the winning team originating from Indonesia. Overall, the winning team was able to install cool roofs in 15 cities on 70 buildings and has also piloted the solution on rural affordable housing structures, with an aim to update future building specifications to include cool roofs. The team measured and verified indoor air temperature reductions of over 10 degrees Celsius in some of the pilots.

46
De Ridder, Koen. 2023. Citizen science project maps heat stress in Johannesburg. Vito, February 21, 2023. https://vito.be/en/news/citizen-science-project-maps-heat-stress-johannesburg. Accessed October 9, 2023.

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Souverijns, N., De Ridder, K., et al. 2022. Urban heat in Johannesburg and Ekurhuleni, South Africa: A meter-scale assessment and vulnerability analysis. Urban Climate, Volume 46, 2022, 101331. https://www.sciencedirect.com/science/article/pii/S2212095522002498#s0035. Accessed October 9, 2023.

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Veldeman, N. 2023. Urban greenery can bring cooling in unbearably hot Niamey. Vito, May 8, 2023. https://vito.be/en/news/urban-greenery-can-bring-cooling-unbearably-hot-niamey. Accessed October 9, 2023.

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For example, see Project Coolbit: Nazarian, N., Krayenhoff, E. S., et al. 2022. Integrated assessment of urban overheating impacts on human life. Earth's Future, 10, e2022EF002682, August 23, 2022. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022EF002682.

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Barteit, S., Boudo, V., et al. 2021. Feasibility, acceptability and validation of wearable devices for climate change and health research in the low-resource contexts of Burkina Faso and Kenya. September 30, 2021. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0257170#sec004. Accessed October 9, 2023.

51
Important for avoiding maladaptation.

Case Study 2

DengueChat

GAPS ADDRESSED

Data Gap

Doing Gap

What problem were they solving?

As climate change lengthens the mosquito season, the geographical range of the mosquito is expanding to new regions and re-emerging in areas where mosquito numbers had subsided for decades. To control dengue and other arboviruses, elimination of potential breeding grounds where the transmitting mosquito reproduces is needed. This is a task generally assigned to the local government. But the water hatcheries which are potential breeding grounds are mostly in the homes of residents, and are clean water storage containers, or small containers that escape government chemical control. The challenge is to motivate residents in affected locations to take action.

What did they do?

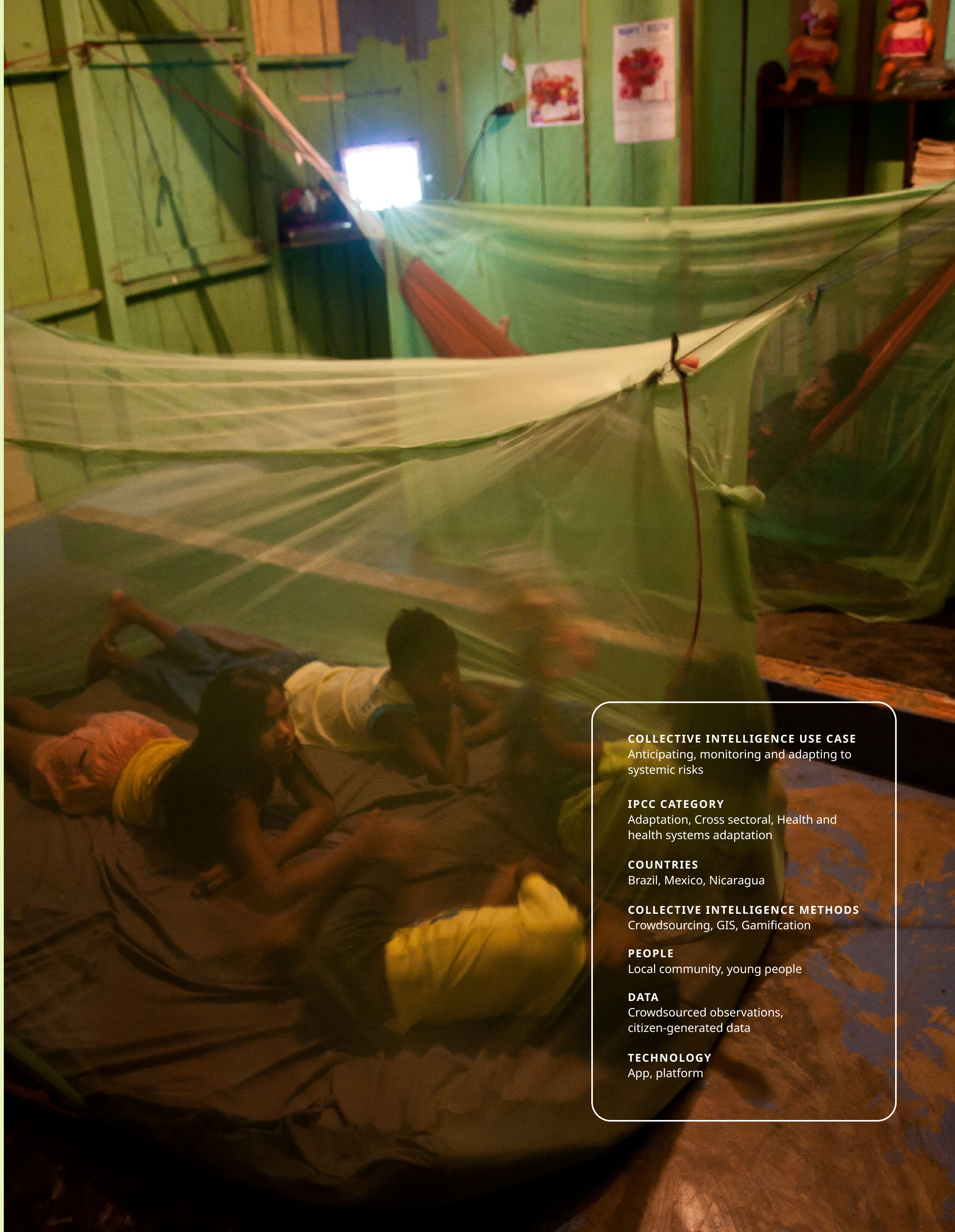
DengueChat is an interactive web and mobile platform that combines mobile technology, data collection, reporting, analysis, pedagogic information and game concepts to motivate communities to participate in dengue vector control. DengueChat (a) crowdsources the identification and mapping of vector breeding sites; (b) motivates communities to act; (c) embodies a user-centered and collaborative model of software design; (d) promotes civic engagement; and (e) involves residents in public health education. DengueChat was developed through participatory technology design involving young user-residents in Brazil, Mexico and Nicaragua. DengueChat crowdsources the identification of breeding sites through photographic evidence, generating data that appear on the website. The web interface is interactive, allowing residents to create their own profiles and blogs and to exchange information regarding dengue and chikungunya in their neighborhoods. Also teams of volunteer youth brigades deploy DengueChat under the supervision of a project facilitator. Through the brigades, young people earn badges and points for their efforts in identifying and eliminating breeding sites.

What was the benefit of using collective intelligence for this issue?

During an 18-month pilot study in Managua, Nicaragua, DengueChat was found to reduce the mosquito transmission for dengue, chikungunya, and Zika by 90 percent in five intervention neighborhoods, while it increased by over 400 percent in five control neighborhoods (where DengueChat was not used). DengueChat's innovative approach to community-based vector control has scaled to other countries since its initial pilot.

What does this experience tell us about collective intelligence for climate action?

Combining community-led data collection, preventative actions by local residents and government programs is an effective way to stem the tide of disease transmission without the use of toxic chemicals. DengueChat engages community members who are affected by the disease, as they are often the best sources of information about active and potential mosquito breeding sites. This helps to build trust between residents and institutions when public officials commit to interventions based on data collected through the project. Residents are also empowered to mitigate against the spread of disease themselves as data about transmissions are shared with them directly.



COLLECTIVE INTELLIGENCE USE CASE
Anticipating, monitoring and adapting to systemic risks

IPCC CATEGORY
Adaptation, Cross sectoral, Health and health systems adaptation

COUNTRIES
Brazil, Mexico, Nicaragua

COLLECTIVE INTELLIGENCE METHODS
Crowdsourcing, GIS, Gamification

PEOPLE
Local community, young people

DATA
Crowdsourced observations, citizen-generated data

TECHNOLOGY
App, platform

The value of collective intelligence for climate mitigation

So far, much of the global conversation on climate action has been dominated by a focus on mitigation, predominantly in the Global North. It's been estimated that 92 percent of emissions are the result of actions taken by the richest countries.[52] We found relatively few examples[53] that used collective intelligence methods for mitigation in the Global South. The most common mitigation options among these case studies focused on forest management practices, specifically ecosystem restoration or reduced conversion of forest land, and waste minimization and prevention.[54]

The three most commonly applied collective intelligence use cases we found were:

USE CASE 3
People generating and using data to create evidence for more effective action to address climate change and its impacts.

USE CASE 4
People developing a shared understanding of natural ecosystems and taking coordinated actions to address climate change.

USE CASE 6
People collaborating to develop, find or implement climate solutions faster.

52
Wrigley, J. 2022. It's time for the Global North to take responsibility for climate change. The University of Manchester, Jul 16, 2022. https://sites.manchester.ac.uk/global-social-challenges/2022/07/16/its-time-for-the-global-north-to-take-responsibly-for-climate-change/. Accessed October 9, 2023.

53
23 case studies out of 106 analyzed.

54
Although activity in these areas has a direct impact on the reduction of carbon emissions, they also have clear complementarity to adaptation actions described in the previous section. For example, waste management practices are often coupled with localized disaster risk reduction activity while localized ecosystem restoration projects are often implemented alongside biodiversity management adaptation.

Mitigation-based collective intelligence projects in the Global South tend to address *doing* and *data gaps,* and span across different geographical scales. For example, several forestry initiatives are international programs where common, well-tested protocols for environmental observation are applied by local level initiatives. Alongside a contribution to coordinating actions, these initiatives help to fill *data gaps* by monitoring progress on a single issue in a standardized way. In contrast, waste management initiatives tend to respond to specific local needs, helping to better coordinate actions between diverse stakeholders in cities. These examples also capture data about the scale of the problem, particularly plastic pollution, or bring additional value by surfacing data about invisible or informal contributions to the waste management ecosystem.

Table 2 provides a summary overview of the three climate mitigation areas[55] where most current collective intelligence practice is concentrated, alongside the key methods and climate action gaps that are addressed. These are described in detail in the text that follows.

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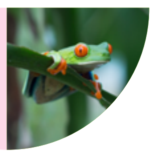
We have grouped *Ecosystems restoration, reforestation, afforestation* and *Reduced conversion of forests and other ecosystems* together, as forest-based initiatives often make contributions to both of these IPCC categories.

Table 2:
Summary overview of the existing areas of application of collective intelligence initiatives for mitigation, organized by IPCC mitigation categories

IPCC MITIGATION CATEGORIES ENABLED BY COLLECTIVE INTELLIGENCE	COLLECTIVE INTELLIGENCE METHODS BEING USED	MAIN CLIMATE ACTION GAPS BEING ADDRESSED
Ecosystems restoration, reforestation, afforestation / Reduced conversion of forests and other ecosystems	Crowdsourcing and remote sensing for forest protection	■ *Data gaps* on real-time threats and long-term trends of forest loss. ■ *Distance gap* through volunteer-led data analysis to fast track scientific research.
	Microtasking and digital tools to scale collective action	■ *Doing gaps* around piecemeal, local actions that fail to connect to global tree-planting targets.
	Combining sensor data and microtasking for intelligent networked actions	■ *Doing gaps* around uncoordinated community activities for forest and other land-use restoration. ■ *Diversity gap* (Indigenous and traditional knowledge) to make more locally-appropriate decisions about interventions.
Waste minimization, reduction and management	Crowdsourcing and combining datasets to monitor global waste	■ *Data gaps* about the precise location, quantity, type and origins of plastic litter. ■ *Doing gaps* around lack of accountability and persistence of behaviors that cause waste build up. ■ *Distance gap* around lack of reliable open data about waste that can be compared between countries.
	Remote sensing and citizen science to manage marine litter	■ *Data gaps* about the scale, types and origins of plastic litter on coastlines. ■ *Data gaps* about hotspots where marine litter is concentrated. ■ *Doing gaps* around accumulation of marine litter. ■ *Distance gaps* around the consequences of plastic waste.
	Citizen generated data and coordinated actions to manage urban waste	■ *Data gaps* about the quantity of and categories of municipal waste at the street level, as well as hotspots of waste build-up. ■ *Data gaps* around contributions of informal waste pickers. ■ *Doing gaps* around how to prioritize limited waste services and waste mismanagement.

Ecosystems restoration, reforestation, afforestation / Reduced conversion of forests and other ecosystems



Ecosystem restoration is among the cheapest climate mitigation measures.[56] Beyond a direct impact on emissions, it also helps to strengthen biodiversity, regulates flooding, enhances water quality and reduces soil erosion — all of which are also important for adaptation. Ecosystem restoration can also provide multiple social benefits such as the creation of jobs and income, especially if implemented in a way that considers the needs and access rights of Indigenous Peoples and local communities.

Restoring just 30 percent of converted lands in priority areas, especially forests, can simultaneously sequester large amounts of carbon and avoid just over 70 percent of biodiversity loss.[57] However, the vast majority of the world's forests are not located in legally protected areas, leaving them vulnerable to deforestation through agriculture, mining, logging and urban development. Destruction of the world's forests also negatively impacts human health, exacerbates food insecurity and undermines the rights of Indigenous and local communities.[58]

Data about the pressures on forest ecosystems are currently incomplete and lack the granularity that differentiate between key drivers of deforestation. Methods like citizen science and remote sensing are being applied to fill *data gaps* that cover both long-term trends and activities happening in real time. Specifically, online citizen science is helping to create labeled datasets about historical degradation at a granularity, speed and scale beyond the scope of the traditional research process and much more cheaply. At the same time, localized, real-time data about illegal logging are supporting smarter, more targeted intercepting actions by local communities and Indigenous groups.

Also at the local level, collective intelligence platforms are being used to coordinate the activities of communities responsible for forest and other land use restoration efforts, helping to overcome *doing gaps*. Several initiatives use remote sensing with drones or satellites to track the contributions made by individual smallholders or villages.

The final subgroup of collective intelligence methods is focused on coordinating tree planting activities (microtasks) and restoration efforts by volunteers around the world. Digital platforms, mapping tools and open repositories are facilitating these efforts and standardizing data collection to allow easier aggregation and comparison between locations. This means that collective intelligence initiatives are increasingly responsible for connecting local action to the global level, by filling *doing gaps* at scale.

Crowdsourcing and remote sensing to protect forests

An estimated 12 to 20 percent of emissions are due to deforestation and forest degradation activities, mostly in the tropics of Africa and South America.[59] Some of this activity is illegal and some is sanctioned due to market pressures that lead to agricultural expansion and building of transport infrastructure. But the scale and sources of deforestation are still poorly understood. Collective intelligence initiatives are helping to address both *data* and *doing gaps* for forest protection. Methods like citizen science are being used to generate new data about key drivers of forest loss in the tropics, while sensor data is helping to alert local communities to illegal logging activities in real time so they can intervene.

One example is the "Drivers of Tropical Forest Loss" crowdsourcing campaign coordinated by the International Institute for Applied Systems Analysis. They used Geo-Wiki, a digital platform for organizing earth observation studies, to mobilize 58 volunteers from different locations who classified satellite images of forests according to visible impact from human activities. The campaign lasted two weeks and used rewards to maintain engagement and quality of contributions. Over this short period, the volunteers managed to review almost 15 thousand locations in the tropics. The dataset has been made openly available to support scientists and decision makers to take action against forest loss and its causes.[60]

Collective intelligence is also being used to track real-time forest loss in the Amarakaeri Communal Reserve in Peru. Community guards from local Indigenous groups use the Mapeo app and drones to monitor degradation activities that threaten the forest ecosystem, from informal mining to illegal logging. The app supports data collection in the field without the need for an internet connection. When individual guards return to base, they upload their data to the central Mapeo platform where it is aggregated to give an up-to-date overview of the status of the reserve. The technology can send alerts to rangers if timely interventions are needed and the Amarakaeri community have also used the data for legal action against companies who violate the Reserve's protected status.[61] The Guardian Platform developed by Rainforest Connection is another example that uses low-cost acoustic sensors and machine learning to detect logging activities in South American rainforests to support preventative action by on-the-ground rangers.

56
Pörtner, H.O., Scholes, R.J., et al. 2021. Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change; IPBES secretariat, Bonn, Germany, June 21, 2021. https://zenodo.org/record/4659159.

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Strassburg, B., Iribarrem, A., Beyer, H. et al. 2020. Global priority areas for ecosystem restoration. Nature, 586(7831), 724–729, October 14, 2020. https://www.nature.com/articles/s41586-020-2784-9.

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Lacuna Fund. 2023. Request for Proposals: Climate and Forests - 2023. Lacuna Fund, November 1, 2023. https://lacunafund.org/wp-content/uploads/sites/11/2023/03/Climate-and-Forests-2023-RFP-Final.pdf. Accessed October 9, 2023.

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Grantham Research Institute and The Guardian. 2023. What is the role of deforestation in climate change and how can 'Reducing Emissions from Deforestation and Degradation' (REDD+) help? The London School of Economics and Political Science, 10 February, 2023. https://www.lse.ac.uk/granthaminstitute/explainers/whats-redd-and-will-it-help-tackle-climate-change/. Accessed October 9, 2023.

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Laso Bayas, J.C., See, I. et al. 2022. Drivers of tropical forest loss between 2008 and 2019. Sci Data 9, 146, April 1, 2022. https://doi.org/10.1038/s41597-022-01227-3.

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Earth Defender's Toolkit. ECA-Amarakaeri: Monitoring the Amarakaeri Communal Reserve in Peru. (Website). https://www.earthdefenderstoolkit.com/community/monitoring-the-amarakaeri-communal-reserve-in-peru/. Accessed October 9, 2023.

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Baghdjian, Alice. 2023. Can planting trees really help us tackle climate change? Zurich Insurance Group, October 01, 2023. https://www.zurich.com/en/media/magazine/2021/can-reforestation-uproot-climate-change. Accessed October 9, 2023.

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Kim, Soo. 2022. While COP was talking, K-pop has been planting. The Lead, November 19, 2022. https://thelead.uk/while-cop-was-talking-k-pop-has-been-planting. Accessed October 9, 2023.

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KPOP4PLANET met with the Korean government and entertainment companies to discuss how they could adopt more sustainable practices: Smith, Ian. 2022. 'No K-pop on a dead planet': Meet the stans taking up climate activism. euronews.green, November 28, 2022. https://www.euronews.com/green/2022/11/28/no-k-pop-on-a-dead-planet-meet-the-stans-taking-up-climate-activism. Accessed October 9, 2023.

Microtasking and digital tools to scale collective action

Trees are one of the most effective nature-based solutions and contribute to mitigation directly through carbon storage. They also provide indirect environmental benefits through flood risk reduction, improved air quality and habitat restoration which impacts biodiversity. But without strategic planning and coordination, tree planting and restoration efforts can fail to deliver on their promise.[62] Collective intelligence initiatives help to localize tree planting through selecting the most appropriate tree varieties and planting sites. Online platforms are being used to develop open repositories of restoration projects, resources and tools to help volunteers to find local-level projects more easily, and fast-track progress through peer exchange. Digital tools are also supporting the coordination of global planting efforts. Volunteers across the world make small individual contributions through microtasks, which are aggregated for collective impact. In combination these methods are mobilizing large groups of people for action — helping to fill important *doing gaps.*

Plant-for-the-Planet's open source Treemapper platform facilitates mapping, coordination and resource sharing for tree planting projects across the world (see Case Study 3). Their online digital impact tracker provides daily updates of trees planted globally and the estimated aggregate impact on carbon emissions. A similar initiative that is trying to unify and connect local level projects through a global platform is the open repository of restoration initiatives set up by the Restor Foundation. Their platform aims to democratize access to ecological data by ensuring that restoration data is created for, and with restoration practitioners. Members of the Restor community can upload information about their own projects, search for other projects and data, monitor the impact of restoration activity with satellite imagery or exchange insights with others. By 2023, the repository contained information and data about more than 77,000 restoration initiatives around the world.

Another example is KPOP4PLANET, a global climate activist platform launched by K-pop fans, via the Fandom 4 Forest initiative, which maps out the number of trees planted by fans in different countries so far. The data suggests that global fans of BTS, Blackpink and other major K-pop stars, have planted 113,824 trees through at least 212 projects across 21 countries. These "K-pop forests" have reportedly absorbed more than 28,000 tons of carbon dioxide.[63] This initiative shows the benefit of collective intelligence efforts that tap into an existing community with a strong common identity to guarantee engagement and achieve impact at scale. The activism at the heart of K-pop fan culture is drawing the attention of governments and corporations,[64] encouraging them to be more ambitious in tackling the climate crisis.

Combining sensor data and microtasking for intelligent networked actions

Communities living in regions most affected by climate change often hold unique knowledge about effective management strategies for the local context and can identify more appropriate or inclusive solutions. Collective intelligence initiatives in this space rely on multiple hyperlocal communities and individuals taking small actions (microtasks). These small-scale actions can be verified through sensor data or field surveys, and when aggregated, help to achieve impact at the collective level — closing the *doing gap.*

The Biodiversity Conservation project of the Cacheu Mangroves National Park in Guinea Bissau[65] established a 24-member oversight committee of residents from local villages and national authorities to agree on a local action plan for restoration. Working with a technology provider, they first used GIS and satellite data to map and select the most viable sites for restoration. They focused restoration activities on these sites. Community members and staff from national parks were involved in tracking important environmental indicators such as bird populations, soil quality and sapling height, etc., to monitor impact. Over three years the initiative established 8,000 hectares of community-managed forests and restored 200 hectares of mangroves. By bringing together public sector officials and communities from the outset, they managed to identify more appropriate and acceptable solutions for all parties. For example, they adopted a technique that let tidal flows transport mangrove seeds to reduce the cost of planting. The project also provided input into the national government's agenda for wetland restoration and conservation, helping to fill a *decision-making gap.*

Another example where many individuals are involved in taking small manageable actions for collective impact is the Vietnam Forests and Deltas programme from Winrock.[66] Communities are rewarded for the provision of environmental services ranging from soil protection and restoration to forest management. The programme is also piloting forestry-based carbon sequestration services to offset industrial carbon emissions. The actions taken by communities are recorded using a digital app and verified through field surveys and GIS technology. The programme uses smart payments to reinforce the adoption of sustainable practices in the long term, allocating up to $130 million a year to more than 500,000 Vietnamese households for their work protecting forests. In addition to improving natural resource management, it has increased resilience of vulnerable communities through support for local livelihoods.

Boomitra is a digital marketplace that finances ecosystem restoration. It uses AI and remote sensing technology to monitor and verify the impact of restoration activities undertaken by farmers on carbon content, nutrients, and moisture levels of soil. This gives rise to redeemable carbon credits, which are sold to corporations and governments worldwide. Proceeds from the sales are sent directly to the farmers, encouraging them to maintain behaviors and allowing them to reinvest in the source of their livelihood, as well as their community.

65
Wetlands International. 2018. Conserving Biodiversity of the Cacheu Mangroves National Park at Guinea Bissau. August 30, 2018. https://www.wetlands.org/publications/conserving-biodiversity-cacheu-mangroves-national-park-guinea-bissau/. Accessed October 9, 2023.

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Toplic, Leila. 2022. Digital for Climate Adaptation and Resilience of Vulnerable Communities. NetHope, October, 2022. https://nethope.org/wp-content/uploads/2022/10/NetHope_Digital-for-Climate-Adaptation-and-Resilience_First-Installment_October-2022.pdf. Accessed October 9, 2023.

Case Study 3

Plant-for-the-Planet

GAPS ADDRESSED

Doing Gap

Distance Gap

What problem were they solving?

Restoring lost trees is essential to preventing the climate crisis. Trees capture CO2 from the atmosphere and store the carbon in their leaves, stems and roots, eventually increasing the carbon stored in soil. The majority of the carbon capture potential of forests exists in Latin America, Africa and southern Asia. Restoring forests in these regions has many potential benefits to society, including the creation of new economies based specifically on making restoration happen. This may lead to the generation of billions of dollars in income for national and local economies and small landholder farmers. According to Global Forest Watch estimations, deforestation in the three states of the Yucatán peninsula (Campeche, Quintana Roo, Yucatán) accounted for 42.3 percent of all forests lost between 2001 and 2020 across Mexico. Mexico is the home of 12 percent of the world's biodiversity. Nonetheless it suffers from one of the world's highest rates of deforestation.

What did they do?

Plant-for-the-Planet has several dedicated restoration campaigns, notably in Yucatan and Volcano Valley in Mexico. Their open source Treemapper platform is used to map and track tree restoration progress in real-time. The platform allows restoration projects across the world to register and map their efforts (there are partner projects in more than 50 countries). There are online guides for restoration organizations to help run their own campaigns and individual users can also donate trees. Alongside, the programme has an emphasis on training youth ambassadors to advocate for tree planting and broader platforms of climate justice.

What was the benefit of using collective intelligence for this issue?

Plant-for-the-Planet has developed a shared repository of guidelines and tools to help tree restoration projects across the world run their own local campaigns. The shared protocols help to ensure high quality, consistent data standards and precise impact monitoring, which can be aggregated at the global level. Their online digital impact tracker provides daily updates of trees planted globally with an estimate of the impact on carbon emissions alongside a comparison with a no-intervention scenario. The creation of the "monitoring plots" featured on Treemapper has enabled comparison of the impact of the restoration work with non-intervention scenarios. The Treemapper app works in settings with no internet connection. Over the course of 15 years, the program has led to the restoration of more than 12 million trees supported by more than 225 projects. The programme also creates local jobs[67] and trains youth ambassadors to advocate for climate justice and tree planting. The restoration work intersects with other strategies such as livelihood diversification (for smallholder farmers) and carbon capture (in the long term).

What does this experience tell us about collective intelligence for climate action?

Plant-for-the-Planet enables different reforestation campaigns to map their projects on the platform, increasing community resilience and local collective action. The initiative demonstrates the value of developing shared data standards and transferable protocols. This approach has helped local restoration projects to elevate the value of their actions by contributing to global targets. In terms of institutional impacts, visualizing reforestation efforts on the platform provides a quantitative evidence base for the development of more appropriate and feasible policy programmes.

COLLECTIVE INTELLIGENCE USE CASE
Distributed problem solving

IPCC CATEGORY
Mitigation, AFOLU, Ecosystem restoration, reforestation, afforestation

COUNTRIES
Mexico and worldwide

COLLECTIVE INTELLIGENCE METHOD
Crowdmapping

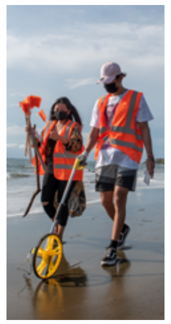
PEOPLE
Young people, volunteers

DATA
Crowdsourced observations, geospatial

TECHNOLOGY
App, cartographic platform

67 In its Yucatan restoration work, Plant-for-the-Planet has created jobs for 121 people.

Waste minimization, reduction, and management



Plastic pollution is a growing source of emissions. By 2050, it's estimated that the emissions from the lifecycle of plastics could be equivalent to 615 large coal-fired power stations.[68] Food waste is another significant source of emissions; it's estimated that discarded food is responsible for six percent of global greenhouse gasses.[69] Both plastic and food waste are growing problems in the Global South where waste management is underdeveloped and a large percentage of waste is mismanaged, particularly in urban settings, ending up in landfill unnecessarily or subject to open burning.

Plastics also contribute to emissions through their build up in marine and coastal environments. Marine litter, especially microplastics, can alter key species and habitats in coastal and marine environments, greatly reducing their carbon absorption capacity.[70] Plastic pollution accumulates in oceans mainly due to poor waste management, littering and overconsumption. Countries in sub-Saharan Africa and South Asia figure prominently among those with the highest volumes of plastic in coastal areas.[71]

Currently, effective waste management and cleanup operations are hindered by *data gaps* about the scale of the plastics problem, particularly in urban and coastal settings in the Global South. Collective intelligence initiatives are drawing on global crowdsourcing and hyperlocal citizen science initiatives to help fill these gaps on the precise location, quantity type and origins of plastic litter. Generating more granular data that captures these details could help to hold polluters accountable, tackling the problem at its source. Equally important is the standardization of data collection to ensure, for example, the use of the same categories of litter to allow for comparison across different locations and periods of time.

Collective intelligence efforts are also helping to fill *doing gaps.* Coastal crowdsourcing and citizen science projects help close the loop between collecting data and taking action through the organization of beach clean-ups. The success of these initiatives is often down to a critical mass of local participants motivated to improve their area after learning about the scale of the problem through data collection. A few initiatives have even helped to inform the redesign of collection, reuse and recycling programs, and the waste policy priorities of local decision makers. But it is rare that these projects have a direct impact on decision-making.

Urban waste management systems rely on the streamlined activity of many actors to function efficiently. To date, the coordination at the scale required has been difficult to implement in cities in the Global South, resulting in mismanagement of waste that leads to unnecessary emissions. Collective intelligence can make a major contribution to addressing this issue. Several examples use digital tools to connect different parts of the waste management ecosystem, from waste producers (households and businesses) to individual service providers across the public, private and informal sectors. In these examples, collective intelligence emerges from the smart matching of supply and demand to address *doing gaps* of ineffective waste management.

Crowdsourcing and combining datasets to monitor global waste

As waste production continues to escalate, it is more important than ever to keep better track of the rate and scale of the problem to target interventions. Collective intelligence helps to fill this *data gap* through crowdsourcing and/or combining datasets about location and types of waste, as well as documenting which brands contribute the most to plastic pollution. These data are increasingly shared through open databases that encourage their sharing and re-use for research and decision making.

The Waste Atlas is an interactive map that provides a reliable source of municipal solid waste management data, dumpsites and treatment plants across the world for comparison and benchmarking purposes. It combines datasets acquired through web-scraping and actively crowdsourced from more than 160 countries worldwide.

Contributors, mostly scientists and official institutions, can submit data in many different formats including images or spreadsheets, but they have to follow a common data standard. All data is verified before being published to maintain quality and can be accessed through either a web-based interface or mobile apps. Other platforms, like OpenLitterMap, crowdsource data about litter and plastic waste from a wider pool of volunteers. It invites citizen scientists to upload geotagged photos and descriptions of litter, providing granular information about the location of the image with a timestamp of when it was created. They can also use the platform to organize local cleanups.[72] The crowdsourced images are labeled with information about the quantity, category of waste and the brand that produced the original product. Similar to Waste Atlas, there is a quality assurance process before the data are integrated into the global map and made available as open data. Volunteers make their contributions through a gamified interface that includes a leaderboard and regular competitions to incentivize engagement.

68
Joshi, Ketan. 2021. Plastics: A carbon copy of the climate crisis. Client Earth, 16 February 2021. https://www.clientearth.org/latest/latest-updates/stories/plastics-a-carbon-copy-of-the-climate-crisis/. Accessed October 9, 2023.

69
Ritchie, Hannah. 2020. Food waste is responsible for 6% of global greenhouse gas emissions. OurWorldInData.org, March 18, 2020. https://ourworldindata.org/food-waste-emissions. Accessed October 9, 2023.

70
Lincoln S., Andrews B., et al. 2022. Marine litter and climate change: Inextricably connected threats to the world's oceans. Science of the Total Environment, September, 2022. https://pubmed.ncbi.nlm.nih.gov/35525371/.

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Sugathan, Mahesh et al. 2022. Substitutes for Single-Use Plastics in Sub-Saharan Africa and South Asia. UNCTAD. https://unctad.org/system/files/official-document/tcsditcinf2022d3_summary_en.pdf. Accessed October 9, 2023.

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As of July 2023 there are a handful of documented cleanups in countries in the Global South, including Indonesia, Brazil and Mexico. (Website) https://openlittermap.com/cleanups. Accessed October 9, 2023.

73
Catarino A.I., Mahu E., et al. 2023. Addressing data gaps in marine litter distribution: Citizen science observation of plastics in coastal ecosystems by high school students. Frontiers in Marine Science, 10:1126895, February 6, 2023. https://www.frontiersin.org/articles/10.3389/fmars.2023.1126895/full. Accessed October 9, 2023.

74
The final implementation phase for the project was expected to take place between September 2022-February 2023 and it is unclear if data collection will continue after this. Ibid. https://www.frontiersin.org/articles/10.3389/fmars.2023.1126895/.

75
The evaluation survey results about the impact of the project on young people, including their awareness of plastic pollution as an issue and intentions to change behavior, are still due to be published.

76
Lor, R. 2021. An experiment on satellite remote sensing of plastic waste in Pasig River. UNDP, September 29, 2021. https://www.undp.org/philippines/blog/experiment-satellite-remote-sensing-plastic-waste-pasig-river. Accessed October 9, 2023.

Remote sensing and citizen science to manage marine litter

Despite increased awareness from policymakers and the public alike of the importance of marine litter as a key pollution challenge, there are still substantial *data gaps* about the scale, types and origins of plastic litter on coastlines. This is especially true for countries in the Global South. Hyperlocal citizen science projects are a good way to bridge between data collection and planning interventions to address the problem. They achieve this by sensitizing local communities to the issue and the scale of its impact, helping to close *doing* and *distance gaps* in the process.

The Citizen Observation of Local Litter in the coastal ECosysTems (COLLECT) project[73] is a rare example of a pilot that aims to fill these gaps by standardizing data collection about marine litter in seven countries in West Africa and Southeast Asia.[74] COLLECT has worked with young people to make observations and measure levels of plastic waste (macro- to micro-plastics) on beaches. Participating students were trained in sampling protocols using simple instruction manuals and YouTube videos available in multiple languages. This helped to ensure consistent data quality and promoted skills development among local young people. A key aim of the initiative is to increase awareness of the potential consequences of plastic pollution among local communities.[75] The data from COLLECT contribute to establishing baseline information on coastal plastic pollution and help to identify hotspots of coastal plastic litter in participating countries.

In the Philippines, the UNDP Accelerator Lab is also trying to quantify plastic litter accumulation in Manila Bay. They are combining satellite imagery and citizen science to monitor the scale of the problem in Pasig City as part of a broader circular economy portfolio. They use satellite data to provide a baseline estimate of marine litter, which will be ground-truthed by local citizen researchers. This participatory approach to waste monitoring is part of an awareness-raising effort they hope will lead to changes in plastic disposal locally.[76]

The Ghana Marine Litter project is another example of working with residents to fill significant data gaps on plastic waste. The initiative connected local grassroots groups with staff from the national statistics office from the outset. This helped to ensure that the data collected by locals would be useful for policy decisions and could contribute to the international monitoring commitments made by the Ghanaian government (see Case Study 4).

Citizen generated data and coordinated actions to manage urban waste

Urban waste management services in the Global South are often provided by a complex mix of official, private and informal actors. Mismanagement can be the result of individuals failing to separate waste or inefficient routing and coordination between the different parties involved in the production, distribution and treatment of waste. The absence of granular data about municipal waste at the neighborhood or street level also leads to doing gaps whereby different parts of the system are not optimized for coordinated action. One common oversight is the contribution made by informal workers, whose activities are important for diverting waste from landfill.

Collective intelligence initiatives in this space are using a combination of ethnographic methods and digital tools to connect the dots. Digital platforms and smartphone apps are helping to improve routing between waste producers[77] and waste management services (both official and informal). Integrated payments and financial penalties that incentivize waste reduction at the level of individuals can result in a collective shift away from actions that increase emissions from waste when aggregated across the city. This also raises awareness about the consequences of mismanaged waste among local residents to help reduce the *distance gap*.

Clean City Africa is a Zimbabwean initiative to streamline waste collection and disposal services that divert recyclable waste away from landfills and prevent emissions from activities like the open burning of waste. Using a mobile app, households and businesses who generate waste are matched with waste collectors and aggregators, including informal workers. Clean City helped to consolidate this ecosystem by providing training and equipment that enabled informal workers to expand their operations. The Clean City initiative facilitates coordination between different stakeholders in the waste management ecosystem to improve environmental outcomes. Since its launch in 2019, over 50 illegal dump sites have been shut down across Harare city and over 10,000 households have started separating materials at source.[78]

A similar example can be found in Bangalore, where 90 percent of litter is sent to landfill largely due to the failure of households to segregate their waste at source. The IGotGarbage project, which ran between 2014-2017 tried to address this through a digital platform that matched informal waste pickers with households and businesses that produced waste. Waste-pickers were trained to collect and manage different waste types, for example, sending recyclable dry waste to scrap dealers and ensuring that wet waste was sent to composting centers. Households had to pay for waste that still got routed to landfill, which led to increased recycling by residents. Over 10 million kgs of waste was recycled and composted while the platform was active.

Mismanagement and build up of waste designated for landfill can also be caused by limited municipal resources and insufficient data. The MOPA (Monitoria Participativa Maputo) platform in Mozambique uses a mobile app and citizen-driven data collection to help cities use limited services more efficiently. Citizens use a digital app to report waste issues like the build up of dumping sites or missed collections across their city. This helps to fill *data gaps* about where the urban waste system is under most pressure so service providers can prioritize those areas for cleanup. The data is aggregated on an open platform where city officials and citizens alike can monitor problems as they arise and monitor trends in service quality over time.

77
Both household and business waste.

78
Mukeredzi, T. 2019. Zimbabwe's private sector is cleaning up its cities — literally. World Economic Forum, Oct 4, 2019. https://www.weforum.org/agenda/2019/10/app-clean-up-zimbabwes-cities-reduce-disease. Accessed October 9, 2023.

Case Study 4

Ghana Marine Litter Project

GAPS ADDRESSED

Data Gap

Doing Gap

Distance Gap

What problem were they solving?

Plastics are the largest, most harmful and most persistent type of marine litter, accounting for at least 85 percent of total marine waste and reducing the carbon absorption capacities of oceans. Marine litter continues to inflict enormous damage on Africa's coastlines, particularly in Ghana, whose coastline stretches more than 550 km and is home to an estimated three million people. Continuous data to monitor marine litter and other environmental indicators in the country is lacking, as well as the ability to use this data to coordinate actions that could reduce the marine plastic burden.

What did they do?

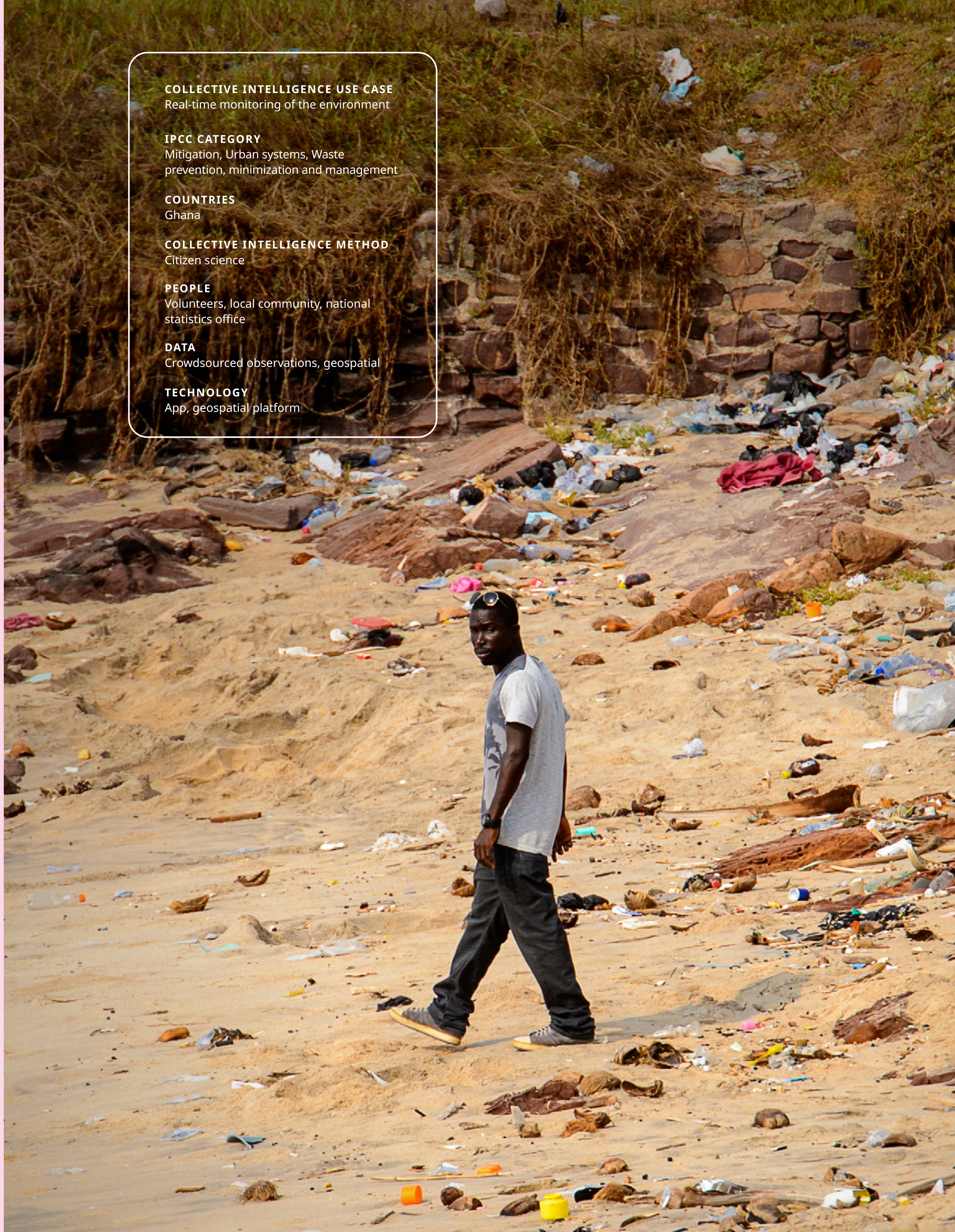
The Smart Nature Freak Youth Volunteer Foundation used the Ocean Conservancy's ICC methodology during their beach cleanups to track marine litter by using data cards and the Clean Swell app to record data on location, weight of debris collected, type of waste and distance covered. This data was then integrated into the Earth Challenge platform to coordinate the monitoring of marine litter nationally in Ghana. The Earth Challenge platform also helped connect partners to local cleanup organizations, such as the Smart Nature Freak Youth Volunteer Foundation and led to direct action such as beach cleanups. The project used off-the-shelf solutions such as Clean Swell which required fewer resources to implement and enabled the reuse of historical data.

What was the benefit of using collective intelligence for this issue?

The project tapped into existing sustainable networks such as Smart Nature Freak Youth Volunteers and Plastic Punch, so that data could be efficiently collected as a by-product of existing activities. In 2020 alone more than 152 million plastic items were found along the beaches in the country. The project coordinated an approach to achieve measurable improvements to waste management in the state of Ghana's seas, waters, beaches, marine biodiversity and fish stocks. This was not only helpful for the country's official SDG monitoring and reporting activities, but also for taking necessary policy actions to address the marine plastic issue in the country. The citizen science data generated through the project helped to understand the items of plastic litter found on Ghana's beaches, as a percentage of total plastic litter over four years. These data also helped to identify that plastic pieces are by far the most common items found on Ghana's beaches. The data also helped to understand the impact of the COVID-19 pandemic on the environment, because in 2020, gloves and masks (personal protective equipment) were found for the first time on Ghana's beaches.

What does this experience tell us about collective intelligence and climate action?

Collective intelligence enabled the use of locally-produced data for monitoring marine litter in Ghana, fostering more efficient data collection through the development of a standardized monitoring protocol. The data collection approach was developed in collaboration with staff from the National Statistics Office, helping to ensure that it could be used for official monitoring as part of Ghana's reporting on SDG targets. The project also contributed towards group level impacts such as increased community resilience and reduced local littering through beach cleanups.



COLLECTIVE INTELLIGENCE USE CASE
Real-time monitoring of the environment

IPCC CATEGORY
Mitigation, Urban systems, Waste prevention, minimization and management

COUNTRIES
Ghana

COLLECTIVE INTELLIGENCE METHOD
Citizen science

PEOPLE
Volunteers, local community, national statistics office

DATA
Crowdsourced observations, geospatial

TECHNOLOGY
App, geospatial platform

Towards closing the decision-making gap

It is clear collective intelligence is already making contributions to several IPCC adaptation and mitigation action pathways. Most existing initiatives focus on advancing understanding of the environment and climate issues through bridging *data, distance* and even *diversity gaps*. There is also promising progress on overcoming *doing gaps* — collective intelligence is involving more people in action on climate change, often achieving this scale through digital technology.

But when it comes to taking policy action and navigating complex trade-offs, we're still lagging behind — we need to focus on *decision-making gaps.*[79] The continued failure of institutions to address these gaps also contributes to widening the *distance gap* between lived experience, public knowledge and climate expertise.

The most relevant collective intelligence use cases to make this transition towards implementation include:

USE CASE 1
People participating at scale in climate-related policy processes, monitoring implementation or documenting environmental violations.

USE CASE 5
People contributing to the design and development of more inclusive climate programmes and technologies.

Due to the paucity of existing practice in these areas, we have drawn on a wider selection of case studies in this section, including examples from the Global North and domains other than climate change to highlight the possibilities for future practice. There are four concrete opportunities for collective intelligence to contribute to decision-making **(Table 3).** Many of the approaches and methods described in this section are at the cutting edge of collective intelligence practice and still need to be validated in different contexts.

79
Hulme, M. 2018. "Gaps" in Climate Change Knowledge: Do They Exist? Can They Be Filled? Environmental Humanities, Vol 10, Issue1, May 1, 2018. https://doi.org/10.1215/22011919-4385599.

Table 3:
An overview of four future application areas to help fill decision-making gaps

	FUTURE OPPORTUNITIES FOR CROSS-CUTTING CLIMATE ACTION	MAIN CLIMATE ACTION GAPS BEING ADDRESSED
	**Public participation in climate policy decisions**	■ *Decision-making gaps* due to complex trade-offs and value negotiations for climate policy options. ■ *Distance gap* around lack of trust in perceived ability of institutions to address climate crisis.
	**Improved modeling to inform climate policy**	■ *Decision-making gap* around failure to anticipate impact of public behavior in response to climate policies and regulations. ■ *Decision-making gap* around lack of local stakeholder buy-in for decisions around natural resource management.
	**Monitoring climate action and inaction**	■ *Decision-making gap* around lack of accountability for failure to follow through on commitments. ■ *Distance gap* around lack of trust in perceived ability of institutions to address climate crisis.
	**Tackling mis- and dis- information**	■ *Distance gap* of misinformation reducing trust in scientific research on causes and impacts of climate change. ■ *Decision-making gap* around mis- and disinformation increasing polarization.

These applications are unique in spanning across both climate adaptation and mitigation. Although there are currently few examples of this type of activity in the Global South, focusing future pilots in these directions will be vital for closing the *decision-making gaps* where progress is most needed.

Public participation in climate policy decisions

Some of the core challenges of climate change are failures of decision-making.[80]

Decisions on transitioning energy sources to renewables, legal and human rights implications of climate-driven migration, and the relative safety of new technologies for carbon removal[81] are often divisive, but timely public deliberation could help mitigate future conflict. These issues lack an obvious "right" answer and governments are reluctant to make decisions out of fear they will generate controversy or backlash from the public. Resolution is needed sooner rather than later — it's estimated that environmental migrants will exceed 1 billion by 2040 and in the same period more than half of the world's population will experience high or extreme water stress.

Using collective intelligence to aid deliberation can help to address stalemate by convening people with opposing views, values and preferences and giving them tools that help to identify shared priorities for action across political divides. There is evidence that these methods can reduce polarization, increase satisfaction with policy outcomes[82] and help to build trust and the perceived efficacy of public institutions.[83]

How might collective intelligence address climate policy decision gaps?

Climate assemblies and Deliberative Polls® are already being used by governments worldwide to understand public policy preferences on contentious issues. In Ireland, assemblies were used to find consensus and define legislation on marriage equality and abortion — two topics that previously divided the country. Some governments, mostly in the Global North, have started to use collective intelligence to help deliberate on climate policy. In the Republic of Korea, a Deliberative Poll® informed the country's policy on nuclear energy. When 60 percent of the nationally representative sample of 500 citizens voted to resume construction of nuclear stations, the government reversed their decision to decommission the sites. Polling or assemblies can also be used to inform climate policy priorities at the international level. In 2020, the Global Assembly selected 100 representatives from across the world to debate different options for climate action. Together, they wrote the People's Declaration for the Sustainable Future of Planet Earth that was presented to world leaders at the COP26 conference that year. Dozens of smaller community assemblies debated the same issues alongside the main global assembly, facilitated by local grassroots organizations worldwide. Overall, more than 1,300 people from 41 countries participated — making it the largest public deliberation on climate policy to date.

Digital games are an alternative way to bring climate policy scenarios to life, allowing members of the public to examine trade-offs associated with policy decisions and offer their preferences for future adaptation or mitigation strategies. They offer a fun and accessible way for people to engage with serious policy decisions. For example, The Strategy Room, developed by Nesta in collaboration with Fast Familiar and University College London, combines digital storytelling about future climate scenarios, deliberation and interactive polling to engage citizens in selecting preferred pathways for achieving net zero in their local areas.[84] In 2023 it was used by 12 municipalities in the UK to identify the most appropriate and popular climate policies that should be prioritized for implementation in their region, engaging over 630 members of the public. The World Climate Simulation is a role-playing game that invites participants to imagine they are taking part in international climate negotiations. It uses a simulation tool called C-ROADS, built on up-to-date climate models, as an input for policy discussions between stakeholders. It's been played by both high-level decision makers and mixed stakeholder groups including members of the public. The results have been used by high-level officials in the US government to support both internal policy discussions and international negotiations.

80
Ibid

81
The IPCC recommends that public participation in governance of carbon removal proceeds alongside research into these new technologies: Pörtner, H.O., Roberts, D.C., Adams, H., et al. 2022. Technical Summary: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, TS.C.13.4, 2022. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_TechnicalSummary.pdf.

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Berditchevskaia, A., Edgar, C., Peach, K. 2023. The Strategy Room: an innovative approach for involving communities in shaping local net zero pathways. Nesta. July 2023. https://www.nesta.org.uk/documents/2826/The-Strategy_Room-report.pdf. Accessed October 9, 2023.

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OECD. 2020. Innovative citizen participation and new democratic institutions: catching the deliberative wave. OECD Publishing, June 10, 2020. https://www.oecd-ilibrary.org/sites/339306da-en/index.html?itemId=/content/publication/339306da-en. Accessed October 9, 2023.

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Berditchevskaia, A., Edgar, C., Peach, K. 2023. The Strategy Room: an innovative approach for involving communities in shaping local net zero pathways. Nesta. July 2023. https://www.nesta.org.uk/report/the-strategy-room-involving-communities/. Accessed October 9, 2023.

Better modeling to inform climate policy decision-making gaps

As climate change radically reshapes our environment, existing computational models and the data that underpin them for understanding trends and making decisions, are no longer sufficient.

Current models fail to account for the uncertainty introduced by people's behavior, because they study environmental variables in isolation and are primarily developed with data from the Global North. This *decision-making gap* could be addressed by integrating datasets from the social and behavioral sciences[85] and policy datasets[86] into climate simulations. However, there are still substantial *data gaps* about public preferences, concerns and opinions around climate policies or climate technologies.[87] Collective intelligence methods like data observatories that capture real-time data about public behavior and attitudes could be used by decision makers to improve mapping between climate policies and behavioral outcomes to fill *decision-making gaps* around adaptation planning.

Climate models can also be designed together with local stakeholders — this is particularly important when modeling the behavior of different stakeholders in relation to natural resource management. Participatory modeling is a promising collective intelligence method that uses models to create a shared understanding of complex climate policy issues. It involves convening different groups with competing priorities to agree on an action plan. This approach could be vital for getting buy-in for local level decisions around natural resource management.

How might collective intelligence address decision-making gaps with modeling?

COVID-19 demonstrated the value of real-time public **data observatories** for insights into population-level behaviors unfolding in real time. In Germany, the COVID-19 Snapshot Monitoring (COSMO)[88] initiative used crowdsourcing, surveys and social media data to generate a dataset about perceptions of risk, as well as understanding and behaviors undertaken by the public during the pandemic. This was used within government modeling of outcomes to explore the potential impacts of different policy decisions on the spread of disease. Likewise, the COVID-ZOE app used citizen science to collect data about real-time changes in people's behaviors and was used to inform pandemic policy in the UK. The same methods could be used to generate data about responses to acute environmental crises and simulate the behavioral impacts of different climate policies.

Agent based modeling (ABM) is a modeling technique that allows decision makers to explore intersecting environmental systems and behavioral data. To date, the use of ABMs for policy has mostly been confined to modeling pandemics and climate-related disasters but there is potential to expand its use to anticipate the interaction between public attitudes, behavior and climate policy. For example, a proof of concept initiative in Haiti used crowdsourced geographic information and other publicly available data to model population movements in the immediate aftermath of disasters.[89] In the future, models like this could support governments and first responders to explore different scenario options for aid distribution to inform better adaptation planning.

Participatory modeling uses a combination of computer simulations, role-play and collective decision making to make future impacts of present-day actions more tangible. In the Philippines, an initiative delivered by the company Deltares used participatory modeling with decision makers from several government departments and organizations in charge of public utilities to design an integrated water management plan for the Tacloban river basin, a region increasingly at risk of water shortages. Another example is where the Muonde Trust, a community-based research organization, partnered with international researchers and local stakeholders to apply participatory modeling to land management in Mazvihwa Communal Area, Zimbabwe.[90] In this initiative, smallholders, local villagers and officials contributed data and helped to design models that represent the current state of the land. This helped to simulate more realistic options for cropland management and ultimately, allowed the groups to reach agreement on future adaptation strategies.

85
Beckage, B., Moore, F.C. & Lacasse, K. Incorporating human behaviour into Earth system modelling. Nature Human Behavior 6, 1493–1502, November 16, 2022. https://www.nature.com/articles/s41562-022-01478-5. Accessed October 9, 2023.

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Flynn C., Yamasumi E., et al. 2021. People's Climate Vote. UNDP and University of Oxford, January 2021. https://www.undp.org/publications/peoples-climate-vote. Accessed October 9, 2023.

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Betsch, C., Korn, L., et al. 2020. COVID-19 Snapshot Monitoring (COSMO Germany) - Wave 1. PsychArchives, 2020. https://www.psycharchives.org/en/item/2f84f750-74f4-4266-912f-fe57d8f3cd91. Accessed October 9, 2023.

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Crooks, A.T., Wise, S. 2013. GIS and agent-based models for humanitarian assistance. Computers, Environment and Urban Systems, Volume 41, 2013. http://www.sciencedirect.com/science/article/pii/S0198971513000550. Accessed October 9, 2023.

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Eitzel, M.V., Solera, J., et al. 2021. Assessing the potential of participatory modeling for decolonial restoration of an agro-pastoral system in rural Zimbabwe. Citizen Science: Theory and Practice, 6(1), February 5, 2021. https://theoryandpractice.citizenscienceassociation.org/articles/10.5334/cstp.339. Accessed October 9, 2023

Monitoring climate action and inaction

Emissions reductions are not on track to reach targets by 2030.[91] This is a good example of a substantial *decision-making gap* where international commitments are not taken seriously, particularly in the Global North.

The OECD's 2021 Trust survey showed low public confidence in the ability of governments to address global challenges such as climate change. This, alongside poor perception of government integrity and dissatisfaction with the lack of participatory or representative opportunities are all contributing to the growing mistrust between institutions and the public.[92] Data is an important tool for civil society to hold governments and industry to account. Several emerging collective intelligence methods in this space are starting to generate new evidence about gaps between public commitments and government or industry action.

How might collective intelligence help close decision-making gaps through social accountability?

Social media platforms are increasingly used as interfaces for **citizen reporting** of environmental violations directly to regulators and companies. For example, a randomized trial in China invited volunteers to use social media platforms to monitor and report on environmental pollution by industry. Over a period of eight months they logged more than 3,000 violations on governmental social media channels. They showed that public complaints made via social media were more likely to lead to regulatory enforcement than private complaints, particularly when posts received a lot of attention from members of the public.[93]

Triangulating between data sources can also be an effective method for identifying environmental violations, particularly if remote sensing data requires on-the-ground verification. In India, the UNDP Accelerator Lab (see Case Study 5) experimented with combining satellite data, crowd labeling and citizen-generated reports about working conditions to identify brick kiln factories that are failing to comply with environmental legislation to regulate emissions.

91
Boehm, S., Jeffery, L. et al. 2022. State of Climate Action 2022. Bezos Earth Fund, Climate Action Tracker, Climate Analytics, ClimateWorks Foundation, NewClimate Institute, the United Nations Climate Change High-Level Champions, and World Resources Institute, Version 1.4. June 2023. https://files.wri.org/d8/s3fs-public/2022-10/state-of-climate-action-2022.pdf?VersionId=2bI20dBIG7CbFLTwjr.FDQkBDw1MNyrP. Accessed October 9, 2023.

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OECD. 2022. Building Trust to Reinforce Democracy: Summary brief presenting the main findings from the OECD Trust Survey. https://www.oecd.org/governance/trust-in-government/oecd-trust-survey-main-findings-en.pdf. Accessed October 9, 2023.

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Buntaine, M., Greenstone, M. et al. How citizen participation affects environmental governance: Evidence from social media in China. VoxDev, November 29, 2022. https://cepr.org/voxeu/columns/how-citizen-participation-affects-environmental-governance-evidence-social-media. Accessed January 15, 2024.

Case Study 5

Brick kiln monitoring in India

GAPS ADDRESSED

Data Gap

Doing Gap

What problem were they solving?

Traditional brick kilns harm the environment, through their high usage of fertile topsoil to make the bricks and the nature of emissions from the chimneys during the firing process. Brick manufacturing contributes eight percent of the air pollution in Delhi and its surrounding districts. In addition, workers at brick kilns often face forced labor conditions.

What did they do?

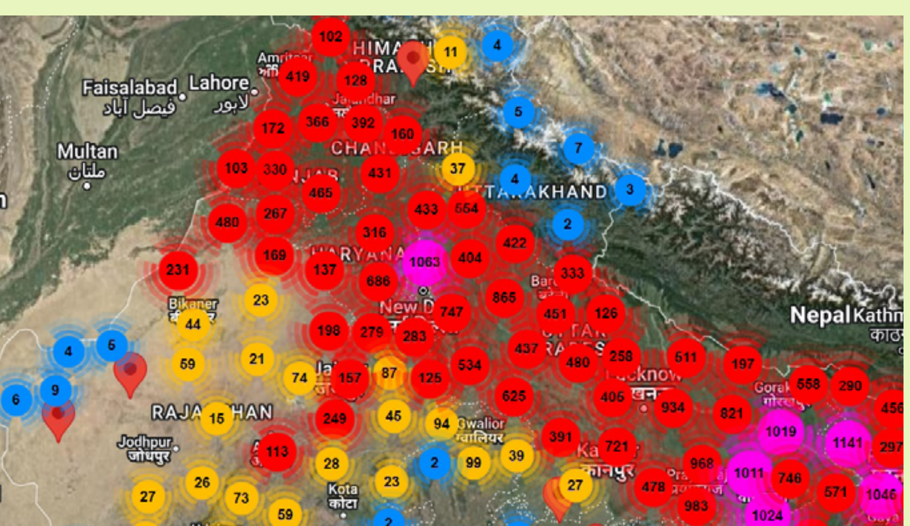
The UNDP Accelerator Lab in India and University of Nottingham developed a new methodology using artificial intelligence — combining machine learning algorithms and geospatial analytics — to map the entire brick kiln belt in India, which has been used by the Bihar State Pollution Control Board to better target environmental policy violations. The GeoAI digital platform detects hotspots of air pollution using satellite imagery and computer vision algorithms (in this case the same algorithm used to identify dog breeds). The partners worked with citizen scientists on the Zooniverse platform to create a labeled dataset of satellite images. This was used to train a computer vision algorithm to detect the specific brick kilns which are hotspots of vulnerable labor and air pollution, uncovering non-compliance with environmental policy in India.

What was the benefit of using collective intelligence for this issue?

As a result, more than 47,000 brick kilns have been detected across Indo-gangetic plains of India and incorporated by UNDP into the GeoAI open data platform. The GeoAI platform is also used to crowdsource reports of violations of labor laws, human rights and social security regulations. Using GeoAI in the State of Bihar, the total number of brick kilns was brought down to a manageable number for staff to inspect. Around 7,500 brick kilns were first analyzed by GeoAI, and it was determined that 1,655 kilns were high risk. Environmental regulators were then able to complete an inspection of 1,013 of those, which led to the green transition of 1,000 brick kilns and the reduction of 500,000 tons of CO2 per annum (equivalent of 100,000 gasoline vehicles). Loans are being secured to help families transition to greener livelihood alternatives.

What does this experience tell us about collective intelligence and climate action?

This experiment brings together coordinated action from diverse stakeholders — regulators, government agencies, civil society and volunteer groups to tackle inaction on environmental commitments. The platform demonstrates the value of automated approaches for improving the efficiency and scale of compliance monitoring efforts. UNDP India is now scaling out this platform to two additional Indian states and in Nepal.[94]



94
UNDP. 2023. The UNDP Accelerator Labs enter a year of maturity: let a thousand flowers bloom. Annual Report 2022. UNDP, May 30, 2023. https://www.undp.org/acceleratorlabs/publications/annualreport2022.

COLLECTIVE INTELLIGENCE USE CASE
New forms of accountability and governance

IPCC CATEGORY
Mitigation, Industry, Material efficiency and demand reduction

COUNTRY
India

COLLECTIVE INTELLIGENCE METHODS
Combining data sources, remote or in-situ sensing, citizen science, AI - computer vision, crowdsourcing.

PEOPLE
Regulators, government agencies, civil society, digital volunteers including local youth from Bihar, India.

DATA
Satellite data, geospatial data, crowdsourced observations

TECHNOLOGY
GeoAI platform, Zooniverse citizen science platform

Tackling mis- and disinformation

The scale and spread of mis- and disinformation is a growing challenge to building an evidence-based understanding of the causes and impacts of the climate crisis as well as the options to address it.

This exacerbates the *distance gap* between scientific knowledge and public knowledge. It also limits the potential of public debate and participatory decision-making by pushing people towards polarization, a key *decision-making gap,* rather than encouraging diverse groups to achieve consensus. Already a known issue in the Global North, there is emerging evidence that climate-related conspiracy theories originating in the USA, can spill over into the Global South to influence local opinion on climate technologies. For example, social media promoting misinformation about "chemtrails"[95] has been shown to negatively impact public perception of solar geoengineering technology.[96] Online disinformation campaigns have been used to deny environmental crimes such as deforestation of the Amazon[97] and have fueled conflict around natural resources in Somalia,[98] while health-related misinformation denying cholera outbreaks has undermined public health efforts and exacerbated the impact of climate-related epidemics in Malawi.[99] Mis- and disinformation in the Global South leverage online spaces like Facebook and, increasingly, private networks like WhatsApp, in addition to spreading through analog means. The emerging use of generative AI models to create content has also raised concerns about the rise of misinformation online as models like OpenAI's ChatGPT have been shown to "hallucinate" or make up facts when they do not know an answer to a user query.[100]

95
A conspiracy theory from the 1990s that alleges condensation trails (contrails) from aircrafts spread chemical or biological compounds for purposes including weather and climate modification.

96
Debnath, R., Reiner D.M. et al. 2023. Conspiracy spillovers and geoengineering. iScience, February 28, 2023. https://doi.org/10.1016/j.isci.2023.106166.

97
Davis, C., Lyra, G. et al. 2020. Social media are fuelling the Amazon's destruction. Nature, 14 April 2020. https://www.nature.com/articles/d41586-020-01078-1. Accessed October 9, 2023.

98
The Sentinel Project. 2021. Fostering misinformation literacy: Runtu Waa Nabad in Somalia. The Sentinel Project, April 16, 2021. https://thesentinelproject.org/2021/04/16/fostering-misinformation-literacy-runtu-waa-nabad-in-somalia/. Accessed October 9, 2023

How might collective intelligence help close the climate misinformation distance gap to support better decision-making?

Most existing examples of collective intelligence to combat misinformation **combine automated approaches and crowdsourcing** for fact checking and moderation of online content. For example, CoFacts is a Taiwanese platform that invites the public to check any text they suspect contains misinformation on the popular messaging platform Line using a chatbot.[101] When statements are submitted for fact checking, they're verified by other CoFacts volunteers. CoFacts aims to curb the spread of misinformation on closed social networks such as chat groups where it can often be difficult to track. In 2018, CoFacts helped users verify messages about LGBTQI+ rights prior to a divisive vote on same-sex marriage.[102] Factmata is another general-purpose tool that can be used to identify harmful online content. They use AI models that are regularly retrained by a community of experts to detect propaganda, hate speech and misinformation in near-real-time.

Another promising collective intelligence approach to curtail the amplification of inflammatory and false content in online spaces is **crowdsourced community moderation.** For example, the r/Science community on Reddit showed that actions taken by existing members, for example regular reposting of community principles, helped to reduce the spread of fake news and increased rule compliance for posted content by eight percent.[103] Crowdsourcing can also help with early detection of misinformation offline. Medicins Sans Frontier (MSF), the International Federation for Red Cross and UN Global Pulse are already developing tools that use social media analysis, crowdsourcing or community reporting to identify and verify rumors that might interfere with response operations during crises. For example, the Wikirumours platform that was developed by the Sentinel Project to crowdsource damaging rumors in conflict-affected regions, has been adapted by MSF to identify disinformation. Spotting new rumors at an early stage allows frontline organizations to adapt so they don't interfere with active programmes in the field.

Online discussions about climate are highly reactive to real-world attitudes and policies around climate. Analyzing how social media narratives change over time could provide valuable insights into policy interventions and agreements that are most successful at shifting societal norms around climate. For example, **sentiment analysis** of public social media discourse showed an increase of 30-40 percent in negative sentiments such as "fear" and "sadness" following the publication of high-profile IPCC reports.[104] Social media can also be used to understand the spread of health-related misinformation. In the wake of the Zika outbreak in 2016, researchers demonstrated the potential of using machine learning and crowdsourcing of social media data to tailor the containment actions of health officials.[105]

99
Pemba, P. 2023. How tackling misinformation is key to cholera response success. UNICEF, February 27, 2023. https://www.unicef.org/malawi/stories/how-tackling-misinformation-key-cholera-response-success. Accessed October 9, 2023.

100
Woodcock, C. 2023. AI Is Tearing Wikipedia Apart. Vice, May 2, 2023. https://www.vice.com/en/article/v7bdba/ai-is-tearing-wikipedia-apart. Accessed October 9, 2023.

101
The Line chat app is very popular in Taiwan.

102
Steger, I. 2018. How Taiwan battled fake anti-LGBT news before its vote on same-sex marriage. Quartz, November 22, 2018. https://qz.com/1471411/chat-apps-like-line-spread-anti-lgbt-fake-news-before-taiwan-same-sex-marriage-vote. Accessed October 9, 20

103
Nesta. CAT Lab: Using CI to mitigate against the negative impacts of AI on online communities. https://www.nesta.org.uk/feature/ai-and-collective-intelligence-case-studies/cat-lab/. Accessed October 9, 2023.

104
Debnath, R., Bardhan, R. et al. 2022. Social media enables people-centric climate action in the hard-to-decarbonise building sector. Scientific Reports vol. 12, November 17, 2022. https://www.nature.com/articles/s41598-022-23624-9.

105
Ghenai, A., Mejova, Y. 2017. Catching Zika Fever: application of crowdsourcing and machine learning for tracking health misinformation on Twitter. arXiv:1707.03778 [cs.SI], July 12, 2017. https://arxiv.org/abs/1707.03778.

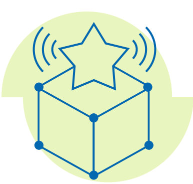
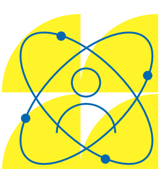
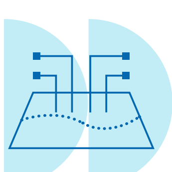
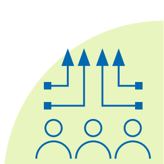
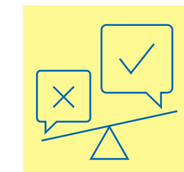
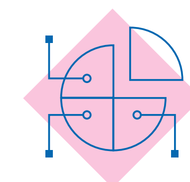
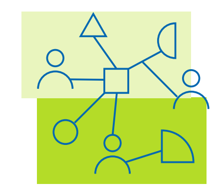
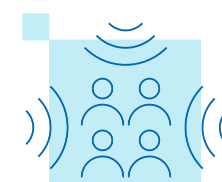
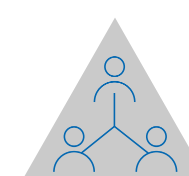
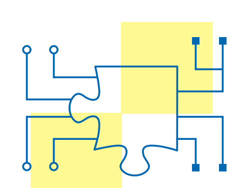
Call to Action: Tap into the intelligence we have

UNDP has already committed to this focus with their Network of Accelerator Labs in 115 countries of the Global South who work directly with the people typically excluded from global knowledge generation. Others need to move beyond the rhetoric of localization to make similar resource investments in the people and places on the front lines of the climate crisis. This will involve breaking some of the cultures, habits and ways of working that have dominated the international development community for many decades.

As the IPCC has shown, time is running out. This may be the last opportunity to use all the tools at our disposal to mobilize our incredible collective intelligence and enable *everyone*, everywhere, all at once to play their part in closing the gaps for more effective climate action.

Glossary: collective intelligence methods

This guide provides a description of key collective intelligence methods referred to throughout this report.

CHALLENGES	DESIGN TACTICS	WHAT IS IT GOOD FOR?	EXAMPLE
Challenge prize 	A competition that offers a financial reward to a person or team who can solve a problem.	Attracting new innovators who might challenge the status quo, or redirecting the efforts of incumbents - encouraging them to think about the problem in a new way.	An offer of seed funding and mentoring is made to innovators who can develop new technologies to help people with health conditions stay independent for longer.
Citizen science 	A process where scientists and volunteers work together to collect or analyze scientific data or observations.	Creating or analyzing high quality data faster, or at larger scale, or with more granularity.	People use a pre-built testing kit to collect local data on water quality which informs research on ecological health.
Crowdmapping 	A type of crowdsourcing that generates information associated with and linked to a specific geographical location.	Creating new, more detailed data about a place more quickly. Can enrich and/or verify 'big data' e.g. from satellites. Also allows people to share information with each other.	People provide detailed information on human rights violations that they have seen or experienced and the location where it took place.
Crowdsourcing 	An umbrella term for a variety of approaches that source data, information, opinions or ideas from large crowds of people - often by open calls for contribution.	Gathering diverse inputs from a wider range of people.	Residents report opinions on the progress of government initiatives via a platform.
Deliberation 	A method of weighing up different options through dialogue.	Weighing up trade-offs on difficult or contentious issues and helping to arrive at more consensus-driven recommendations.	A representative sample of the population is brought together online to discuss and rank policy options to achieve net zero by 2050.
Microtasking 	An umbrella term for when a larger activity is split into small, simple, repeatable tasks that can be distributed among volunteers.	Allows quicker progress on a given challenge and lowers the threshold for contributing, meaning that more people can be engaged.	Individual volunteers in different locations planting trees to achieve regional and global reforestation targets.
Participatory modeling 	People work together to create a realistic model (often digital) of an issue by identifying relevant data inputs, relationships and impacts of different actions.	Helps a group to create a shared understanding of an issue and to explore different options for action.	Local decision makers, water companies and farmers work together to create a model of water use and management in their region.
Participatory sensing 	People using cheap sensors to collectively monitor the environment around them.	Helps to deepen community members' understanding of the issue.	A local community installs devices that help measure noise pollution in their neighborhood.
Peer-to-peer exchange 	People sharing their knowledge or skills with one another.	Fast-tracks learning by sharing most relevant advice and increases likelihood of information being taken up because it comes from people 'like me'.	People share questions over SMS, and then receive back suggestions from others in their community.
Serious (digital) games 	Using game-like elements to make engagement in a project more fun and motivate audiences to explore or contribute to complex topics or research.	Increasing participants' contributions, motivation and retention - enabling the collection of more data, faster.	Students receive points and awards for identifying malaria in blood samples on an online app.

Methodology

This study was carried out from December 2022 to March 2023.

We identified over 100 case studies for our core analysis (page 28, The value of collective intelligence for climate adaptation and page 50, The value of collective intelligence for climate mitigation) of current collective intelligence initiatives for climate action. This analysis was limited to case studies from the Global South that had been active in the period since 2015. This included some case studies that started in the Global North and had expanded to other countries. Focusing on the Global South allowed us to identify the collective intelligence applications that are most relevant and practically feasible for the communities on the frontlines of the climate crisis. The primary analysis was carried out by two Nesta researchers who coded case studies independently and verified each others' work.

To identify emerging and future opportunities (page 66, Towards closing the decision-making gap and PART B – page 102, The Frontier: R&D opportunities for Climate Action), we broadened our analysis to include examples from the Global North and initiatives where collective intelligence is applied to issues beyond climate. Case studies were drawn from existing repositories, as well as a rapid review of the academic and gray literature. The five case studies from UNDP Accelerator Labs featured as standalone boxes were analyzed through semi-structured interviews carried out by a Nesta researcher during August 2023.

We contextualized our findings to broader sectoral trends through a rapid literature review drawing on official reports published by international institutions and development actors (e.g. IPCC, UNEP, WRI), other gray literature and peer-reviewed publications. We tested an early version of our findings with seven experts through two semi-structured interviews and a facilitated online workshop, held in April 2023.

accelerator labs

Co-building the Accelerator Labs as a joint venture with:

german cooperation DEUTSCHE ZUSAMMENARBEIT | QATAR FUND FOR DEVELOPMENT صندوق قطر للتنمية | UNDP Core Partners

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