Immunisation: a critical pillar of climate adaptation

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Gavi
The Vaccine Alliance

Contents

Cover image: Kenya farmers take up fishing as Lake Victoria overflows, threatening human health Credit: Angeline Anyango

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Executive summary

Key messages

- Climate change significantly impacts health by increasing outbreaks of infectious diseases, driving displacement and disrupting health systems.
- The impacts of climate change on health disproportionately affect vulnerable groups such as children, women and displaced people, with health workers facing increased risks, especially during extreme climate events.
- Immunisation prevents several climate-sensitive infectious diseases, promotes health system resilience and is an enabler of climate adaptation, particularly for vulnerable communities.
- Integrating immunisation into national climate processes, including national adaptation plans, can enhance health systems resilience and reduce climate-related health risks.

The climate crisis is a health crisis

Climate change is a direct driver of morbidity and mortality. It alters the environmental conditions underlying transmission of infectious diseases such as malaria, dengue, cholera and yellow fever, enabling them to spread to areas beyond their traditional geographical scope. More intense and frequent extreme weather events further increase the risk of disease outbreaks by disrupting health service delivery and accessibility, just as demand for healthcare drastically increases during a health emergency. Vulnerable people, households and communities, especially those living in lower-income countries, are disproportionately exposed to climate-related health risks. Children, women, displaced persons and communities in remote, fragile and humanitarian contexts experience unique challenges that further increase their vulnerability. Health workers, in turn, face increased risks from extreme temperatures, poor air quality and the physical demands of responding to climate-related health emergencies.

Vaccines are critical to climate change adaptation strategies

The United Nations Intergovernmental Panel on Climate Change (IPCC) identifies vaccines as an effective tool for climate adaptation. Multiple vaccines against climate-sensitive diseases already exist, including malaria, dengue, cholera, yellow fever, Japanese encephalitis, meningococcal and typhoid. By building individuals' resilience against contracting climate-sensitive diseases, vaccines help reduce the risk of severe illness, hospitalisation and death from these diseases. This helps mitigate the strain on healthcare resources and personnel, allowing for more effective coordination of health responses to climate-related health emergencies. Access to vaccines is also an enabler to vulnerable communities' capacity to adapt to the climate crisis. By preventing illness, vaccines also reduce the risk of vulnerable communities from falling into extreme poverty from out-of-pocket health expenditures, lost productivity, or dropping out of school to sustain the family's livelihoods. Increasing evidence has further pointed to an overlap between communities missing out on vaccines and communities least able to withstand climate-related shocks.

Opportunities to mainstream immunisation in climate adaptation

Despite growing evidence on the role of vaccines in climate adaptation, immunisation programmes have not yet been fully considered in the design of most national adaptation strategies. Climate adaptation financing in the health sector, including for immunisation, has also been historically low. This highlights the need for **integrating immunisation programmes as a health response into national-level climate policy processes**, such as national adaptation plans (NAPs), health national adaptation plans

(hNAPs), and Vulnerability and Adaptation (V&A) assessments, to prevent cascading health emergencies and strengthen health system resilience. At the international level, the inclusion of **a health metric on immunisation in the measurement framework of the Global Goal on Adaptation (GGA)** currently being negotiated could be an important contribution to assessing how adaptation efforts are reducing the burden of climate-sensitive diseases, strengthening health system resilience and reaching the communities most vulnerable to the impacts of climate change. Climate financing partners also need to **allocate greater levels of funding to health programmes** that contribute to climate adaptation.

Conclusions and recommendations

Today up to 3.6 billion people around the world live in areas vulnerable to climate change, and the impacts of climate change are expected to intensify. The ability of a country's health system to withstand these impacts will be dependent on the health interventions countries adopt and implement in their adaptation strategies. As such, Gavi, the Vaccine Alliance encourages stakeholders to adopt the following recommendations to enhance the resilience of national health systems and sustain immunisation efforts as part of climate adaptation measures.

Recommendations for governments

- *Prioritise international aid and invest domestic funding on* immunisation services, alongside other proven health measures, to protect people from the increasing risk of climate-sensitive infectious diseases.
- Strengthen supply chains, disease surveillance, early warning systems and health workers' capacity as part of the broader effort to build climate-resilient health systems.
- *Prioritise* the identification of vulnerable groups facing climate-related health threats in national Vulnerability and Adaptation (V&A) assessments, including children, women and displaced populations, as well as community health workers.
- *Include* immunisation programmes and outbreak responses explicitly in national adaptation plans (NAPs), health national adaptation plans (hNAPs) and nationally determined contributions (NDCs), to maximise climate and health co-benefits.

Recommendations for academia

- *Prioritise* research to understand how climate change affects:
    - areas where infectious diseases can thrive, especially those with less data on the climate and health intersection.
    - each stage of the health value chain and health system process for vaccination.
- *Develop* the evidence base on climate adaptation and immunisation, conducting operational research and formative research, to address knowledge gaps on effective strategies to integrate vaccine prioritisation and immunisation activities into national adaptation strategies.
- *Produce, collate* and *evaluate* methodologies to identify groups and communities that are vulnerable to the impact of climate change on health, especially at sub-national level, and encourage their active participation in research.
- *Develop* risk models that reconcile health sector information, such as immunisation coverage and presence of 'zero-dose' children, with climate data to anticipate the impacts of extreme weather events on health, particularly on this population and their communities.

Recommendations for civil society organisations (CSOs)

- *Collaborate* with governments in identifying and providing services to populations and communities vulnerable to the health impacts of climate change, including those exposed to the risks of climate-sensitive infectious diseases.
- *Advocate* for the design and implementation of climate and health adaptation measures, such as immunisation, especially by mobilising community-based organisations, youth movements, women's groups and health workers.
- *Promote and monitor* the engagement of individuals, families, communities and civil society in the development and implementation of national adaptation plans (NAPs), health national adaptation plans (hNAPs) and nationally determined contributions (NDCs).
- *Support* community-level activities, such as training community health workers on how to strengthen vaccine delivery and other essential services during heatwaves, floods and droughts or any other climate event; and integrate these activities with climate action and disaster risk-reduction efforts.

Introduction

In 2024, for 12 months in a row, and for the first time in recorded history, global average temperature increase exceeded the 1.5°C target agreed under the Paris Agreement to prevent global temperatures from rising by more than 1.5°C above pre-industrial levels.[1] The United Nations Environment Programme (UNEP) projected that current global mitigation policies put the world on a path for a temperature increase of 2.6–3.1°C over the course of the 21st century.[2]

The climate crisis presents the greatest threat to human health and existence. A recent study of 375 known infectious diseases found that 218 of them can be aggravated by climate change,[3] including both water-borne and vector-borne diseases. In the majority of countries where Gavi, the Vaccine Alliance provides support, the negative impact of climate change on the transmission of infectious diseases is already being felt,[4] particularly by the most vulnerable and marginalised populations. These people and their communities often have the least capacity and resources to adapt to ongoing and future climate change, but they bear a disproportionate burden of the worst impacts and human costs of climate.[5] The climate crisis amplifies the unique risks and vulnerabilities faced by children and women. As many as 80% of people displaced by climate change are women, while 400 million children globally live in areas highly exposed to tropical cyclones.[6]

In recent years, there has been increasing interest in the intersection of climate change and health, particularly the impacts of climate change on infectious diseases, as well as a recognition of the role of immunisation[7] and other preventive, anticipatory approaches to mitigate the health risks of climate change. Despite growing evidence and urgent need, national immunisation strategies and immunisation against climate-sensitive diseases are often not specifically integrated into, or aligned with, national climate adaptation strategies. The flow of climate finance in health programmes also remains significantly low. Estimates suggest that only 6% of climate adaptation funding is allocated to projects aimed at improving human health, compared to over a third for sectors like infrastructure.[8]

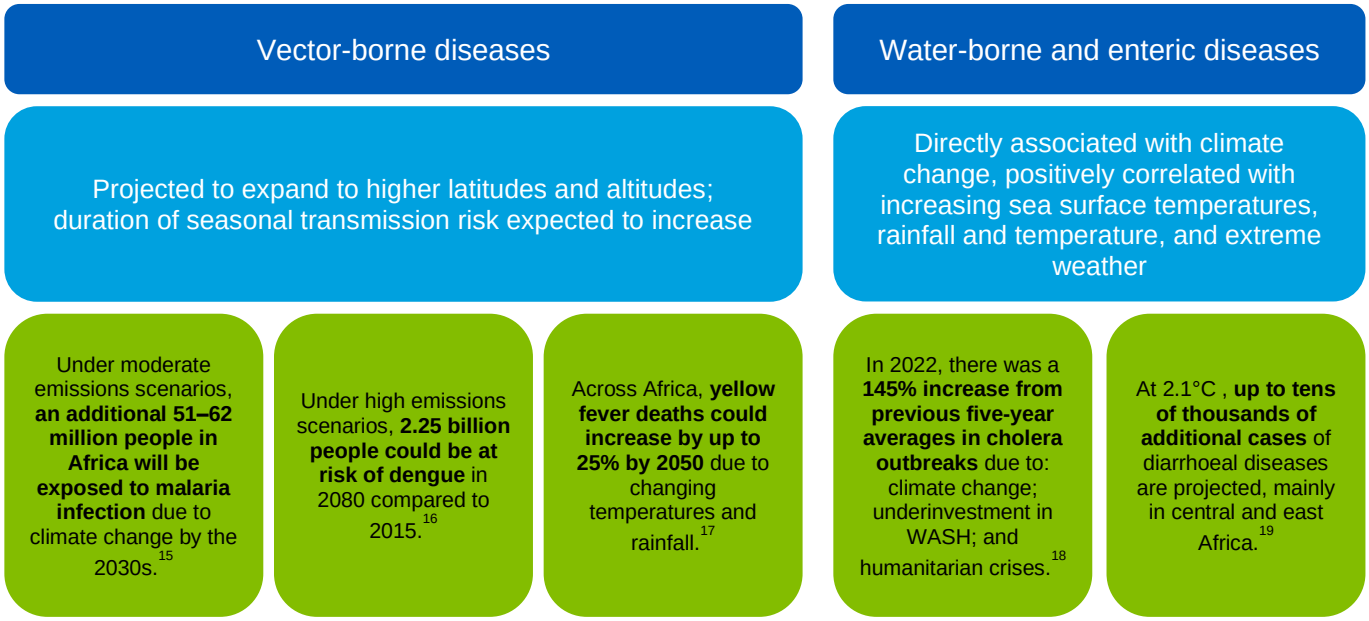
This technical paper, developed with support from the Cambridge Economic Policy Associates (CEPA), and in consultation with multiple national, regional and global experts working on the intersection of climate change and health, aims to make the case for the **integration of immunisation as an effective anticipatory measure into climate adaptation strategies** in support of national, regional and global climate adaptation efforts.

Impact of climate change on health

Climate change has a significant impact on disease outbreaks

Among impacts such as heat stress, floods and droughts, climate-induced changes in temperature and precipitation are a driver of new infectious disease dynamics.[9] Increases in rainfall and more frequent and extreme weather events are, for instance, increasing the opportunities for mosquitoes to breed, increasing their spread and the transmission of vaccine-preventable mosquito-borne diseases such as malaria,[10] dengue and yellow fever. In 2023 alone, 597,000 people died from malaria.[11] By 2030, an additional 51–62 million people will be exposed to malaria infection due to climate change.[12] The World Health Organization (WHO) estimated that, even under the most optimistic scenario, an additional 60,000 and 48,000 people will die from malaria and diarrhoeal diseases, respectively, every year between 2030 and 2050 because of climate change.[13] Likewise, the climate suitability – the favourable climate-related parameters affecting a virus's survival and transmission – of the dengue virus has increased over the past four decades, and dengue cases reached a record high of more than 12 million in 2024 from 70 countries globally, particularly in Africa, the Indian subcontinent, South-East Asia and coastal areas of continental Europe.[14]

Figure 1. Impacts of climate change on vector- and water-borne disease transmission



Climate change is a driver of displacement

Today an estimated 3.3–3.6 billion people live in areas vulnerable to climate change, particularly in Africa, Asia, Central and South America, and small island states.[20] According to the UN Refugee Agency (UNHCR), around 70% of refugees and 80% of people internally displaced by conflict come from countries that are also highly climate-vulnerable, and four in every ten refugees are hosted in highly climate-vulnerable countries.[21] Climate change is expected to increase displacement and human migration even further.[22] If current rates of natural disasters of the past decades continue, as many as 1.2 billion people could be displaced by 2050.[23] Overcrowding, poor access to sanitation and limited access to safe drinking water – conditions often associated with climate disasters and human migration – further put vulnerable people at heightened risks of life-threatening infectious diseases that are vaccine-preventable.[24] Increased displacement is expected to bring new challenges, including worsening long-standing disease burdens, and introduction of novel health risks and health system disruption.[25] Climate change is also expected to alter the geographic range of animals, facilitating human-animal contacts and in turn the emergence of zoonotic diseases of pandemic potential.

Climate change increases health system vulnerability

The number of climate-, weather- and water-related disasters have already increased five-fold since 1970.[26] Data from the Internal Displacement Monitoring Centre (IDMC) has shown that floods and storms have consistently been the leading causes of disaster-related displacements throughout the years.[27] More frequent and extreme weather events could damage essential health infrastructures, and climate-induced health impacts are projected to account for an additional US$ 1.1 trillion extra costs to health systems by 2050.[28] The associated disruption to access and delivery of health services further increases the risks of cascading health emergencies and disease outbreaks.[29]

This is further compounded by the emergence and resurgence of vector- and water-borne diseases in the aftermath of climate-related disasters, such as the cholera outbreak following the severe flooding in

the Far North region of Cameroon in 2024.[30] As the risks and exposure to climate-sensitive infectious diseases continue to rise, so too will the strain on health systems. Climate change is already disrupting population health planning, service delivery and acute healthcare in many parts of the world. Experience has shown that health systems are often ill-equipped to respond to the scale of infectious disease outbreaks and public health emergencies seen in recent years.[31] Health workers across the world are stretched to the limit and facing increased risks during extreme climate events.[32] Climate change is also expected to fuel demand for more refrigeration and cold chain equipment, with particular needs in lower-income countries.

The impacts of climate change on health are felt disproportionately by the most marginalised populations

Climate change is a threat multiplier – it aggravates the social determinants of ill health for vulnerable people, households and communities already facing adversity and multiple deprivations.[33] These vulnerable groups often have few options to adapt except by choosing between harmful coping practices, such as foregoing seeking healthcare or dropping out of school to sustain the family's livelihoods when threatened by climate-related disasters.[34]

Children are particularly susceptible to climate and environmental shocks because they are physically and physiologically more vulnerable, and are at greater risk of death from climate-sensitive diseases. Recent research on the number of children exposed to climate and environmental hazards, shocks and stresses estimated that 600 million children, or one in four children globally, are highly exposed to vector-borne diseases, 400 million highly exposed to cyclones, 330 million to riverine flooding and 240 million to coastal flooding.[35]

People in low- and middle-income economies, especially those facing fragility and humanitarian crises, as well as communities living in remote and rural areas, are particularly vulnerable to the impacts of climate change.[36] Geographical isolation and smaller community populations, for instance, can face challenges with inadequate or outdated health infrastructure, putting communities at heightened vulnerability to disruption of access and provision of health services.

Health workers face significant challenges when delivering healthcare and service in acute climate events, including their personal safety and physical and mental well-being.[37] This is further compounded by the gender inequities in the health workforce: women account for 67% of the global health workforce,[38] putting them at the very forefront of health emergency responses. Despite their critical role in running health systems, women only hold 25% of leadership roles in health[39] and are, therefore, excluded from the critical phase of decision-making in emergency response, where their voices and expertise are needed the most.[40]

Supporting the scale-up in financing and planning needed to adapt health systems to climate change

Addressing climate change effectively requires targeted investments that strengthen human and community health resilience. Any investments that help communities and health systems address and adapt to the effects of climate change are considered health adaptation investments.

A forthcoming report from Gavi assessing the flow from climate finance in health programmes shows that adaptation financing in the health sector has historically been relatively low: health programmes accounted for only 0.5% of climate financing, and only 6% of adaptation funding is currently allocated to projects that protect or improve human health.

A key driver of this low investment is a limited understanding and standardised framework on what qualifies as health adaptation investments, and insufficient data to accurately assess adaptation contributions.

Turning to the process of national planning, national adaptation planning has been improving and in 2024, 171 countries had at least one national adaptation planning instrument[41] and the total number of countries with a health national adaptation plan (hNAP) increased to 43 in 2023 (23 of which have been developed since 2020).[42] Significant gaps remain though: 26 countries do not have a national planning instrument, and development of hNAPs as well as implementation of strategies has lagged.[43]

The critical role of immunisation on adaptation

"The impacts of the climate crisis will be disproportionately felt around the world and will have a direct impact on vaccine-preventable diseases. The best and most cost-effective way to deal with these impacts are through prevention rather than treatment, therefore making vaccination (a) 'low-hanging fruit' as a climate change adaptation approach."

– Global health researcher

Vaccines can prevent several climate-sensitive diseases

The United Nations Intergovernmental Panel on Climate Change (IPCC) has identifies vaccines as an effective tool for climate adaptation across its assessment reports[44] – for a good reason. There are already multiple vaccines prevent climate-sensitive diseases, including cholera, malaria, dengue, yellow fever, Japanese encephalitis, meningitis and typhoid.[45] Gavi-supported preventive vaccinations averted 2.21 million deaths from yellow fever, a climate-sensitive viral disease, between 2000 and 2023.[46] A landmark study published in *The Lancet* in 2024 found that, overall, vaccination against 14 diseases has prevented the death of 154 million people over the past 50 years.[47] It is expected that an additional 51.5 million deaths will be avoided by vaccinations administered between 2021 and 2030.[48]

Immunisation, when implemented alongside other proven health measures, such as vector control management, early warning systems, improved water and sanitation systems, and heat action plans, protects people from the risk of severe illness from climate-sensitive infectious diseases, hospitalisation and death. As a result, country stakeholders are increasingly emphasising that immunisation is an important pillar in the climate change adaptation agenda.

Roll-out of the malaria vaccine: a milestone for the Democratic Republic of the Congo

Malaria is a mosquito-borne disease caused by a parasite, and occurs in tropical and temperate regions throughout the world. Infected people usually have fever, chills and flu-like illness, and they may develop severe complications and die; about three quarters of malaria deaths are in children under five.[49]

The Democratic Republic of the Congo (DRC) faces unique challenges from the impacts of climate change. Its large population of vulnerable communities, combined with low access to public services and infrastructure, and the increasing frequency and intensity of climate-related shocks such as floods and droughts, are expected to have severe impacts on development and health.[50] Malaria is already a leading cause of mortality in the country, with 27 million cases recorded in 2022.[51] Projections anticipate climate change resulting in changes in the transmission of communicable diseases, including malaria. Climate change hazards such as higher temperatures and humidity are likely to extend the seasonality and geography of malaria transmission. By 2050, cases may triple in existing malaria-prone areas, while an additional 65,000–80,000 people may face endemic risk in areas previously unsuitable for malarial mosquitoes.[52] The Notre Dame Global Adaptation Initiative (ND-GAIN), which helps countries measures their vulnerability to climate change to guide national policy responses, highlighted DRC as one of the top five countries most vulnerable to the impacts of climate change.[53]

In a major public health milestone, the country successfully integrated the malaria vaccine into its national routine immunisation programme in October 2024 with its introduction in the province of Kongo Central, with support from Gavi and partners. The vaccine is used to protect children in areas of intense and moderate transmission, with plans for a phased approach to scale up in the remaining provinces of the country in 2025.[54] When used together with insecticide-treated bed-nets, preventive treatment and insecticide spraying, vaccines play a key role in reducing morbidity and mortality. This milestone achievement has inspired significant hope and reinforced the need to ensure increased affordability and availability of vaccines for key climate-sensitive diseases such as malaria and cholera.

Strengthening immunisation promotes health system resilience

"Immunisation is a mirror into the health system."

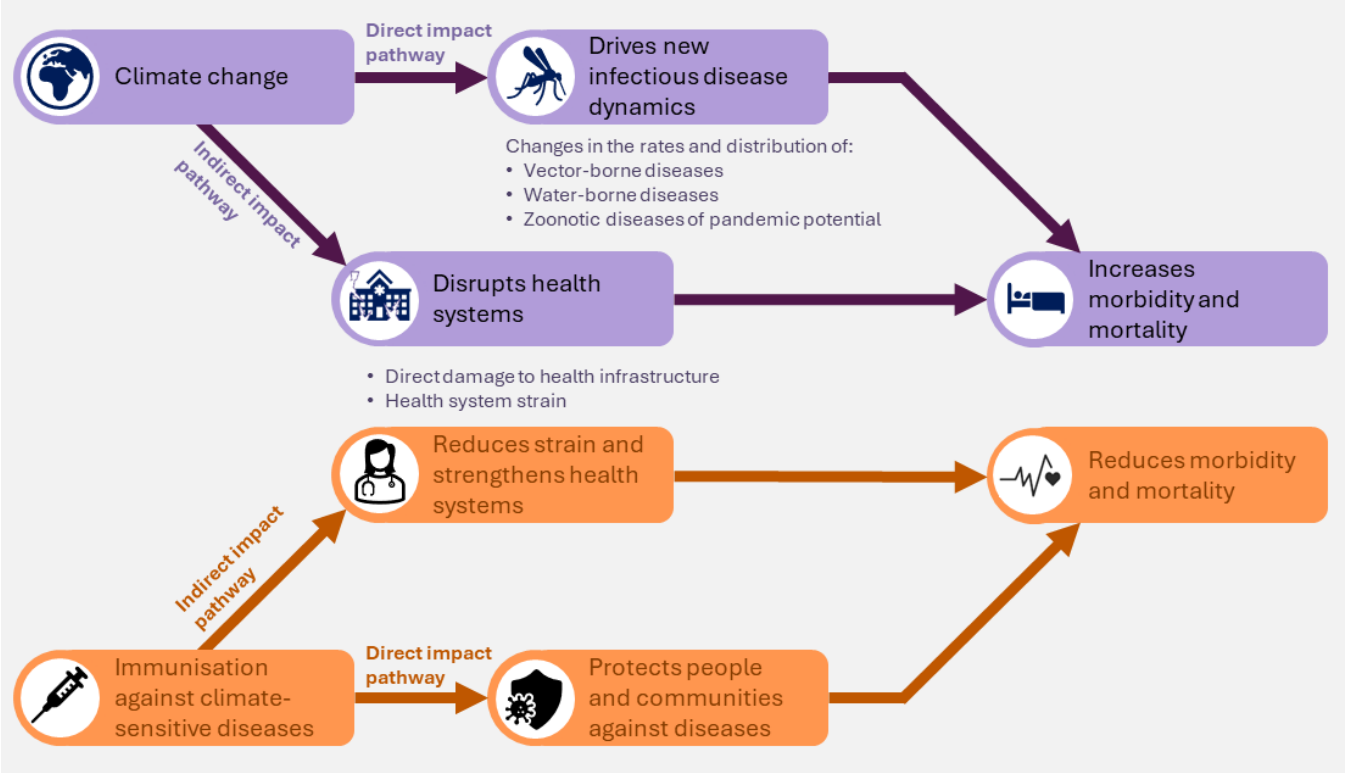
– Ministry of Health focal point in a Gavi-eligible country

By reducing the overall burden of climate-sensitive infectious diseases, vaccination helps to decrease the number of patients who may require treatment and hospitalisation, thereby helping to mitigate the strain on healthcare resources and personnel, allowing for more effective coordination of health responses to climate change, and contributing to greater health system resilience, particularly for the most vulnerable communities.[55] Parallels can be drawn from the COVID-19 pandemic, whereby studies have shown that vaccination reduced the need for emergency care and hospitalisation.[56, 57]

Certain activities implemented to reinforce the capacity of immunisation programmes may also contribute to both climate adaptation and mitigation. For example, the solarisation of the cold chain, health facilities, warehouses and storage units provide access to locally generated clean electricity, thus strengthening the resilience of immunisation and other health programmes to climate-related shocks and disasters, such as heat events or power outages. This move to clean energy also contributes to the reduction of industry greenhouse gas emissions, which countries can include in their

nationally determined contributions (NDCs) – the national climate action plans that countries submit to the United Nations Framework Convention on Climate Change (UNFCCC) to reduce greenhouse gas emissions and adapt to climate change.

Figure 2: Immunisation contributes to counteracting some of the climate-related morbidity and mortality



Vaccine access is an enabler for the most vulnerable communities to adapt to the impacts of climate change

"When a population is well vaccinated, herd immunity allows for greater protection, including populations that do not have the same facility of access to services."

– WHO climate and health expert in Gavi-eligible country

Extending coverage of immunisation services and accessibility to vaccines underpin the capacity of vulnerable and marginalised communities to mitigate their vulnerability to health shocks and ill health related to climate change. By preventing illness and the need for hospitalisation, vaccines reduce the risk of people, especially the economically disadvantaged, being pushed into extreme poverty from out-of-pocket health expenditures, lost productivity, or having to take harmful actions such as dropping out of school. A study covering 73 Gavi-supported countries shows that every US$ 1 spent on immunisation in the 2021–2030 period will save US$ 54 in healthcare costs, lost wages and lost productivity due to illness and death.[58]

A wealth of evidence has also shown the complementarity of immunisation and nutrition interventions. Children who suffer from infectious diseases, including vaccine-preventable diseases, are at an

increased risk of poor nutrition. Repeated bouts of diarrhoea have been known to be associated with up to 43% of stunting cases.[59] Conversely, studies have shown that children in communities with high overall levels of immunisation also tend to have better nutrition status.[60, 61]

Immunisation is also the only intervention that brings the majority of households into contact with the health system five or more times during the first year of a child's life – more than any other primary health care (PHC) intervention.[62] Aligning these touchpoints with other PHC services, particularly for communities and groups most vulnerable to the effects of climate change, will bring substantial spillover benefits to strengthening the ability of countries and their health systems to address climate and health risks.

This is why identifying and reaching 'zero-dose' children and missed communities must be at the heart countries' health priorities. Zero-dose children are children who have not received any vaccine in their lives. Defined operationally as children who have not received the first dose of diphtheria, tetanus and pertussis (DTP)-containing vaccine, they are often found clustered in communities beyond the reach of existing government service provisions, such as healthcare, nutrition, access to sanitation and clean water, and education, or living in fragile and humanitarian contexts. The multiple deprivations experienced by their communities has left them among the most vulnerable and with the least capacity and resources to adapt to ongoing and future impacts of climate change.[63]

Reaching zero-dose children, therefore, helps national health systems to identify and prioritise communities that are vulnerable to climate change, and to deliver more comprehensive PHC and essential services to build their resilience and preparedness against climate-related shocks, enabling a cycle of better health outcomes and well-being.

Where zero-dose children and climate change meet: Nigeria's V&A assessment

Nigeria has made significant progress in improving vaccination coverage over the last decade – increasing the proportion of children who have received basic vaccination from 23% in 2008 to 62% in 2023. Much needs to be done to reach the country's national target of achieving an average national coverage of 80% of children vaccinated by 2028, and Nigeria has the highest number of zero-dose children in the world. According to 2023 estimates, 2.1 million children in Nigeria had not received the first dose of DTP-containing vaccine.[64, 65] In particular, immunisation coverage is lowest in the north of the country, an area also affected by armed conflicts and displacement.[66]

Revealingly, this is also the same zone which Nigeria's recent Vulnerability and Adaptation (V&A) assessment identified as the least able to withstand climate-related shocks. [67]

Nigeria's V&A assessment projected an additional 21% burden of disease due to climate change. This includes an increase in cases of malaria and yellow fever, a significant increase in typhoid fever from just over 1 million cases in 2020 to almost 2 million cases projected in 2030, and an increase in the proportion of diarrhoeal-related deaths linked to climate change to 9.8% in 2030 for children aged under 15. It concluded that more extreme weather events will impact healthcare capacity, increase the vulnerability of communities, and create conditions conducive to greater disease incidence and prevalence in the country.

The alignment between Nigeria's assessment and zero-dose children is not coincidental. Rather, it illustrates how climate change is amplifying the deprivations and inequalities faced by communities, disproportionately affecting the vulnerable and most disadvantaged people, including zero-dose children.

Reaching zero-dose children will not only be critical to managing the spread of vaccine-preventable climate-sensitive diseases, but also for identifying the very vulnerable communities that are disproportionately affected by climate change needing stronger attention and support at all levels.

Vaccination programmes are contributing to the climate and health learning agenda

Efforts are also being made to conduct national health and climate vulnerability assessments, and to refine the spatial and temporal mapping and surveillance of climate-sensitive diseases to develop proactive rather than reactive or emergency-based climate-sensitive vaccination plans.

For example, Gavi, the Vaccine Alliance has collaborated with the International Rescue Committee (IRC) to conduct risk assessments on the impacts of climate change to health infrastructure and human migration in countries that are part of the Zero-Dose Immunization Programme (ZIP). ZIP is a partnership launched in 2022 to identify and reach vulnerable populations across 11 countries in the Sahel and Horn of Africa regions (Burkina Faso, Cameroon, Central African Republic, Chad, Niger, Nigeria, Mali, Ethiopia, Somalia, South Sudan and Sudan).[68] In many of these countries, populations frequently move across porous borders. Natural disasters, such as flooding, often displace these populations, making it difficult for governments to trace them.

A Global Vaccine Risk Index has also been proposed to identify countries that are vulnerable to the emergence and re-emergence of vaccine-preventable diseases, which takes into account factors such as vulnerability to climate change, poverty, fragility and socioeconomic determinants of health.[69] Gavi and other partners are supporting the development and roll-out of novel vaccines for climate-sensitive diseases, such as the global malaria vaccination programme that has since supported the introduction of the malaria vaccine into routine immunisation of 19 endemic countries to provide essential financial support for the procurement, transport and roll-out of doses.

Policy opportunities to mainstream immunisation in climate adaptation plans

Vaccines are essential to ensuring healthy lives and promoting individual, community and health system resilience against climate-related health threats. In the 28th Climate Change Conference, governments adopted a Declaration on Climate and Health, which officially enshrined health in the UNFCCC agenda, and stated that health should be taken into account in the design of national adaptation plans and nationally determined contributions.[70]

At national level, these provide key strategic opportunities for integrating national immunisation programmes into national climate policy processes, such as national adaptation plans (NAPs), health national adaptation plans (hNAPs) and Vulnerability and Adaptation (V&A) assessments, to ensure vaccines are able to deliver their climate and health co-benefits of reducing risks and vulnerability to climate-sensitive diseases, reducing demand on health systems, and enhancing resilience against health-related climate emergencies.

Vaccine responses in Pakistan: a case for integration in National Adaptation Plans (NAPs)

The disastrous flood in June 2022 affected 33 million people in Pakistan, and damaged almost 1,500 health centres, leaving many communities cut off from healthcare services. The flood triggered outbreaks of a range of diseases, including those that are climate-sensitive, as well as those that arise due to disruption to health access and services.[71] Malaria cases also grew four-fold and reached 1.6 million cases in 2022, particularly in the Balochistan and Sindh provinces.[72] Balochistan also recorded diarrhoea rates that were five times higher than normal in October 2022.[73] A surge of dengue infection was also detected across the country, and 25,932 dengue cases were reported between July and September that year.[74] Ongoing outbreaks of measles and polio in the region were also at risk of being exacerbated.[75]

In response, various efforts have been implemented to address the outbreaks of infectious diseases. The Government of Pakistan established a National Strategy for Cholera Control and Prevention and deployed the oral cholera vaccine,[76] and over 500,000 people received treatment for diarrhoeal diseases across various medical camps in July.[77] Led by national authorities, health workers supported by Gavi and partners travelled by boat to vaccinate children with typhoid, measles and rubella, and polio vaccines. Remarkably, the campaign was a success and reached its target of 5.5 million children in Balochistan.[78, 79, 80]

This experience highlights the need for immunisation as a health response to extreme weather events, to prevent cascading health emergencies and strengthen health resilience. It also demonstrates how the emphasis on prevention can contribute to a country's climate and health adaptation strategy. In the aftermath of the flood, the Government of Pakistan developed the country's National Adaptation Plan (NAP).[81] The NAP was viewed as an urgent imperative for the country and was developed under an accelerated timeframe of nine months. It prioritises health and focuses on three main objectives: (1) mainstreaming climate adaptation in health policies; improving data collection and analysis and outbreak forecasting; and integrating adaptation measures into health policies; (2) enhancing climate resilience through disaster emergency preparedness and response; and (3) building workforce capacities to address climate risks. Building on the experience from the flood, the explicit integration of national immunisation programmes into Pakistan's NAP will be key to support the health system's preparedness and adaptation efforts against climate change in the future.

At global level, there is wide consensus that climate-sensitive diseases are a key health threat that must be addressed in the Global Goal on Adaptation (GGA) process. The GGA was adopted in 2015 under Article 7 of the Paris Agreement in COP21. It aims to enhance adaptive capacity, strengthen resilience and reduce vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the Paris Agreement's temperature goal. The UAE-Belém process, initiated at COP28 and to be completed in November 2025 at COP30, is developing a series of indicators to assess progress on adaptation.[82] Health is one of the seven target areas under consideration, and stakeholders are urged to pursue the objective of *"attaining resilience against climate change related health impacts, promoting climate-resilient health services, and significantly reducing climate-related morbidity and mortality, particularly in the most vulnerable communities".*[83]

Given the critical role of immunisation for building climate-resilient health systems, it will be important for the GGA framework to measure relevant immunisation data. A health metric on immunisation coverage under the GGA, if included, could make an important contribution to assessing whether adaptation efforts are reducing the burden of climate-sensitive diseases and strengthening health system resilience, as well as reaching the communities most vulnerable to the impacts of climate change.

'Breadth of protection' against climate-sensitive diseases

'Breadth of protection' is an important indicator representing the extent to which people are protected against key vaccine-preventable diseases.[84] It is calculated as the mean coverage of a full course of WHO-recommended vaccine antigens.[i] The indicator is compiled by WHO annually based on data provided by national health authorities, and reported in the Immunization Agenda 2030 (IA2030),[85] the current global strategy adopted by WHO Member States to strengthen global immunisation efforts, and inform how health ministers and other leaders develop immunisation programmes and set priorities.

Building on this concept, there is scope for the GGA to include an indicator that adapts the methodology of the breadth of protection based on coverage of vaccines and other health measures against a list of climate-sensitive diseases. The burden of climate-sensitive diseases will depend on the local epidemiological context, and in turn what interventions countries adopt in their adaptation strategies, based on their national circumstances.[86] Indicators of health service coverage are some of the best ways to track progress in providing health services. This would also provide an outcome-oriented composite indicator to monitor genuine progress to adapt to the impacts of climate on health.

While an internationally agreed list of climate-sensitive infectious diseases is still to be developed, there is increasing evidence on which those are.[87] A subset of those infectious diseases can be prevented by vaccines including yellow fever, malaria, dengue, cholera, meningitis A, Japanese encephalitis and typhoid, among others.[88]

On climate and health financing, there is a clear need to support financing partners in allocating greater levels of funding to health programmes with a climate adaptation impact. Gavi's forthcoming report will introduce an investment framework for health sector investments, outlining the climate adaptation components across various types of programmes. The framework reveals that immunisation against climate-sensitive diseases ranks among the most effective health investments in terms of climate adaptation impact. This new lens will enable financing partners to maximise the climate adaptation impact of their investments, potentially attracting new sources of climate finance. Ultimately,

[i] These include diphtheria, tetanus, pertussis, hepatitis B, *Haemophilus influenzae* type B, measles first dose, measles second dose, pneumococcus, oral poliovirus vaccine, inactivated poliovirus vaccine, rubella, rotavirus and human papillomavirus.

this evidence-based framework will empower financing partners to maximise the climate resilience of their investments and help to attract new sources of climate finance in health portfolios.

In addition to adaptation benefits, immunisation programmes can also deliver climate change mitigation benefits through solarisation and low-carbon manufacturing and delivery. Under the Paris Agreement, countries must update their nationally determined contributions (NDCs) by 2025, including options for climate mitigation and adaptation.[89] The development of an NDC is unique to each country, reflecting specific circumstances, capabilities and priorities in their response to climate risks. The NDCs, as well as the next round of the Global Stocktake – a stocktake of progress towards meeting the goals of the Paris Agreement, which will start in 2026 – present another opportunity for immunisation to be integrated into national and global climate policy instruments.

Recommendations: immunisation as a preventive approach towards climate adaptation

Universality and equity must be at the heart of climate adaptation strategies if they are to be successful. Targeted investments in integrated, preventive health measures to protect against key health risks and vulnerabilities, especially for vulnerable groups such as children, women, displaced populations and hard-to-reach communities, can effectively increase resilience and minimise the chances for emergencies to escalate into further health hazards. Vaccines can deliver important climate and health co-benefits: lowering the risks of individuals contracting climate-sensitive infectious diseases. This helps reduce people's vulnerabilities to the hazards of disease outbreaks, and in turn reduces the strain on health systems during emergencies when their services are needed the most. We encourage stakeholders to adopt the following recommendations to enhance the resilience of national health systems and sustain immunisation efforts as part of climate adaptation measures.

Recommendations to governments

- *Prioritise international aid and invest domestic funding on* immunisation services, alongside other proven health measures, to protect people from the increasing risk of climate-sensitive infectious diseases.
- Strengthen supply chains, disease surveillance, early warning systems and health workers' capacity as part of the broader effort to build climate-resilient health systems.
- *Prioritise* the identification of vulnerable groups facing climate-related health threats in national Vulnerability and Adaptation (V&A) assessments, including children, women and displaced populations, as well as community health workers.
- *Include* immunisation programmes and outbreak responses explicitly in national adaptation plans (NAPs), health national adaptation plans (hNAPs) and nationally determined contributions (NDCs), to maximise climate and health co-benefits.
- *Establish* multisectoral collaboration committees, including interministerial collaboration between stakeholders working on climate change adaptation, health and immunisation to avoid siloed working, with meaningful participation of civil society, local communities and affected populations.

Recommendations to academia

- *Prioritise* research to understand how climate change affects:
    - Areas where infectious diseases can thrive, especially those with less data on the climate and health intersection.
    - Each stage of the health value chain and health system process of vaccination.
- *Develop* the evidence base on climate adaptation and immunisation, conducting operational research and formative research, to address knowledge gaps on effective strategies on vaccine prioritisation and immunisation activities integration into national adaptation strategies.
- *Produce, collate* and *evaluate* methodologies to identify groups and communities that are vulnerable to the impact of climate change on health, especially at sub-national level, and encourage their active participation on research.
- *Develop* risk models that reconcile health sector information, such as immunisation coverage and presence of zero-dose children, with climate data to anticipate the impacts of extreme weather events on health , particularly on this population and their communities.

Recommendations to civil society organisations

- *Collaborate with* governments in identifying and providing services to populations and communities vulnerable to the health impacts of climate change, including those exposed to the risks of climate-sensitive infectious diseases.
- *Advocate* for the design and implementation of climate and health adaptation measures, such as immunisation, especially by mobilising community-based organisations, youth movements, women's groups and health workers.
- *Promote and monitor* the engagement of individuals, families, communities and civil society in the development and implementation of national adaptation plans (NAPs), health national adaptation plans (hNAPs) and nationally determined contributions (NDCs).
- *Support* community-level activities such as training of community health workers on how to strengthen vaccine delivery and other essential services during heatwaves, floods and droughts and any other climate related event, and integrate them with climate action and disaster risk reduction efforts.

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