

The Impact of Climate Change on Health: Reducing Risks and Increasing Resilience in the Era of COVID-19

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Executive Summary

The climate crisis has many consequences – among them **widespread health impacts** that will lead to immense societal, ecological, and economic harm.

Over the past two decades multiple large-scale reviews on climate change and health have made clear the need for a multi-sectoral approach to target the drivers and impacts of climate change, biodiversity loss, and ecosystem degradation. Despite this abundance of scientific evidence underscoring urgency of action, policy implementation responses lag behind. Even at COP26, itself delayed due to an ongoing pandemic, health continues to be considered by many countries a problem independent from climate and environment.

Recent findings indicate the scale of the problem:

Risk. Once viewed as a future impact, climate change has now been linked to dozens of extreme weather events and temperature anomalies. These have both direct and indirect effects on health, and are posing elevated risk across many impact areas: infectious disease, cardiovascular health, mental health, malnutrition, respiratory health, and others. Anthropogenic activities which have caused climate change and the sixth extinction crisis are simultaneously weakening ecosystems, resulting in an increased risk of disease spillover and reducing capacity to mitigate the impact of extreme weather and heat. Uncertainty associated with climate change also puts food systems at risk globally - heat and precipitation have direct impact on crops, warming oceans influence fish stocks, and changes in local weather threaten pollinators.

Burden. By the end of the century, the yearly burden of temperature-related mortality alone is projected to nearly match the current impact of obesity: reaching 4.6 million annual deaths, or 6th on the 2017 Global Burden of Disease risk factor list. This is *in addition to* air pollution illness and deaths, as well as the wide range of other direct and indirect impacts of climate change not yet systematically evaluated for global burden - from climate-sensitive infectious diseases to food and water insecurity, famine, forced migration, conflict, and flooding. It is clear the disease and death toll of climate change will be higher than what health systems are prepared for today. This burden will be disproportionately experienced by the poor and worsen gender inequalities.

Missed opportunity. The importance of protecting ecosystems and better understanding ecosystem-health dynamics has been made abundantly clear by the COVID-19 pandemic. We are missing an opportunity for climate action, biodiversity conservation, food security, economic stability, and pandemic risk reduction. We are losing carbon sinks, increasing spillover potential for the next pandemic, and diminishing the ecosystem services we depend on for our health. And we are doing so while missing an opportunity to bring collective solutions toward the achievement of the Sustainable Development Goals.

The limited inclusion of health considerations in climate policies results in hidden externalities generally expected to be magnitudes higher in response cost compared to what would be required for prevention.

Climate change stands to also exacerbate other growing global health challenges, such as the risks posed by antimicrobial resistance (AMR) and non-communicable diseases. While the physical impacts of climate change on infrastructure are the most direct and visible, the health impacts of climate inaction will create a pandemic of climate-induced health impacts- one which no vaccine can solve. At the same time, it is becoming increasingly clear that the health sector is not only highly vulnerable to the impacts of climate change, but it is also a significant emitter of greenhouse gases, representing at least 4.4% of net global emissions. **It should seem obvious that the necessary transition to prepared and resilient health systems must also be a green and climate-smart one.**

Some countries, like the UK, are already taking action with strong health sector leadership to reduce emissions. However, a major shift in practice, resourcing, and priorities will be needed to effectively mitigate and adapt to the health risks and consequences of climate change. This paper emphasizes multi-sectoral “One Health” and “Planetary Health” approaches to reduce climate change-related health impacts. Recommendations:

1. Mainstream health into climate change and biodiversity agendas and fund health programs within the United Nations Framework Convention on Climate Change, ensuring technical agencies can support implementation of the Rio Conventions and meet targets agreed to in the Paris Climate Accords and forthcoming Global Biodiversity Framework Targets.
2. Integrate health impact assessment in all development project appraisals and implement appropriate safeguards, with attention to acute and long-term climate-associated effects.
3. Assess and quantify the health co-benefits of proposed environmental investments (e.g. REDD+) to optimize resources, minimize potential trade-offs, and make the health value of mitigation-focused interventions visible.
4. Expand health prevention-related investments in policy, research, and practice in nature-based solutions that have climate, economic, and ecosystem co-benefits.
5. Commit to making climate-smart human and animal health systems universal, including by building in energy efficiency targets by development institutions as part of COVID-19 recovery efforts.
6. Incorporate environmental considerations into multi-sectoral coordination mechanisms (such as One Health platforms) to better align National Action Plans on Health Security and AMR with National Adaptation Plans.
7. Support widespread access to and behavior change for uptake of individual self-protection and risk reduction measures to lessen the occurrence and impact of disease.
8. Increase application of existing climate and health forecasting tools and early warning systems for human and animal health (such as those promoted by the WMO-WHO joint office) and the use of climate data for health at national, regional, and subnational levels.
9. Increase overall prominence of climate considerations in health security priorities and financing, including through the forthcoming Global Plan of Action for One Health, within WHO to mainstream climate across programs.
10. Strengthen the management capacity of relevant government ministries to implement policies and generate technologies to address climate change and climate-sensitive health impacts.

Introduction

“The greatest threat to global public health is the continued failure of world leaders to keep the global temperature rise below 1.5° C and to restore nature. Urgent, society-wide changes must be made and will lead to a fairer and healthier world. We, as editors of health journals, call for governments and other leaders to act, marking 2021 as the year that the world finally changes course.”

- Atwoli et al., “Call for Emergency Action to Limit Global Temperature Increases, Restore Biodiversity, and Protect Health”, published in 230 health journals on September 5th, 2021.

The health impacts of climate change are real, growing, and urgent. They have been extensively understood for decades, but with each passing year, the world sees greater climate disasters, greater harm, greater loss of life, and greater health-related expenditures associated with these threats. The most recent Intergovernmental Panel on Climate Change (IPCC) report (AR6 WG1: *Physical Science Basis*), published in August 2021 and written with the input of over 800 experts, highlights the breaching of physical thresholds - namely temperature rise - that will lead to continued and accelerated health consequences.¹ These impacts have been comprehensively described over the past two decades in academic literature and policy reports. The report released in August is the first of three parts; the remaining two are currently being reviewed and revised for a 2022 IPCC-consensus publication (the last version of which is available from 2014) – which is likely to highlight the greater certainty and severity of climate change-induced health effects, some of which are already being felt, and make clearer the links between nature and humans. Its valuable mitigation and adaptation insights can only be expected to reinforce the urgent necessity for health sector – and indeed every sector - leadership and the extreme economic, health, security, and moral costs of inaction.

The incredible scope of climate-health impacts makes a clear case for taking action to mitigate climate and health risks upstream (prevention) while also adapting to their downstream impacts (preparedness and response). Unprecedented action is needed to both reduce greenhouse gas emissions and adapt to the changes that are already underway. Fortunately, even without specific understanding of climate-sensitive health impacts, outcomes can be improved. Much like other impacts of climate change, they will disproportionately affect the most vulnerable and marginalized, and threaten to increase health-related gender inequalities.² Basic improvements in public health, such as vaccinations, provision of clean water and sanitation, and improved capacity for disaster response, can greatly strengthen vulnerable populations’ ability to withstand the negative effects that climate change will have on communities, livelihoods, and health.

Crises like the COVID-19 pandemic reinforce the need for multi-sectoral and multi-lateral global coordination to fully assess and manage threats to health. Climate-associated health impacts add to an existing burden of disease and an increasing suite of threats to health security – with climate change and climate variability often considered ‘threat multipliers’ by also compounding risks and impacts from other sources.³ Effects of climate change have made control of COVID-19 all the more challenging, and have exacerbated impacts (see ‘burden’ section below). Additionally, many epidemic and endemic disease threats in humans and animals are environmentally-mediated, and in some cases are increasing in their suitable geographic range along with the frequency and intensity of conditions that increase risk of climate-sensitive disease transmission. In fact, many of the drivers of climate change and biodiversity loss directly overlap with the drivers of emerging infectious diseases.^{4,5}

Addressing global priorities provides an opportunity to achieve important climate-related co-benefits. Certain actions can reduce emissions of climate-altering pollutants while also improving health.⁶ Examples of these include: reducing local emissions of air pollutants from energy systems; providing access to reproductive health services to support family planning to improve child and maternal health, improve socio-economic conditions especially for women, and reduce population growth, energy use, and emissions; shifting consumption away from animal products in high-meat-consumption societies or

segments of the population; designing rail and other transport systems that promote active transport (e.g. walking, biking) and reduce use of motorized vehicles, to lower emissions, increase physical activity and improve air quality; and interrupting and reversing the drivers of disease emergence like deforestation that also contribute to loss of carbon sinks. Projections of a high-ambition scenario employing some of these measures in nine countries suggest over eight million lives could be saved by 2040 by avoided air pollution-, diet- and physical inactivity-related deaths.⁷ These measures demand greater attention, offering non-pharmaceutical alternatives to shift from our increasing reliance on treating sickness after it occurs to preventing disease threats outright.

While ambitious targets have been set for both climate and biodiversity, achieving them has failed to date. For example, the international community achieved none of the 20 targets they agreed to in 2010 in Aichi, Japan to arrest the catastrophic loss of biodiversity we are witnessing globally. This insufficient action is pushing our species and planet into risk of “a catastrophic outcome for health and environmental stability”.⁸

Scope

This white paper highlights some of the primary links between climate change and health, including economic implications of business-as-usual scenarios, and showcases how climate and health policy interventions can be optimized by embracing a broader approach (e.g. One Health or Planetary Health). The scope of health impacts linked to climate change is wide and covered in detail in prior references (among them WHO 2021, Watts et al. 2015-2020, and WHO-CBD 2015) and our 2015 review on multi-sectoral causes and impacts (“Climate Change and Health: Transcending Silos to Find Solutions”).⁹⁻¹⁶

However, as seen from the ongoing, increasing emissions of greenhouse gases, most nations have not implemented adequate policy and implementation responses, leaving populations vulnerable. This paper therefore aims to provide a general orientation, identifying specific actions that can reinforce prevention and preparedness within and beyond the health sector, particularly in light of lessons learned from the COVID-19 crisis. While focusing on threats to health security (primarily understood as infectious diseases and antimicrobial resistance) in this paper as one point of entry, the multisectoral strategies identified can be expanded to address wider scope.

Climate-Sensitive Health Impacts

No country is immune from the effects of climate change, though low- and middle-income countries bear the brunt of health consequences. This is due to many factors, such as relatively weaker health systems, poor sanitation and other critical infrastructure, and lack of access to food security safety nets for those most reliant on subsistence farming, as well as large populations of workers who engage in manual labor in either outdoor settings or poorly climatized indoor buildings.

Climate change has already contributed to poor health outcomes in people around the world, and will continue to do so in the future. Some of these impact areas include:

- Heat stress and cardiovascular failure caused by excessive heat
- Malnutrition and diarrhea from disruptions to sanitation and hygiene infrastructure and reduced water and food supply
- Respiratory (e.g. asthma), cardiovascular, and cancer impacts related to air pollution
- Infectious diseases correlated to changes in temperature, precipitation, and humidity, including vector-borne diseases (e.g. dengue, Zika, malaria, and chikungunya)
- Infectious diseases associated with flooding, inadequate shelter, and reduced water supply (e.g. diarrheal and respiratory diseases)
- Anxiety, despair, depression, and post-traumatic stress disorder associated with climate-induced disasters, forced migration, and related conflicts

- Injuries caused by extreme weather events like heat waves and floods
- Chemical exposures and antimicrobial resistance linked to increased resource demands for food production, vector control, and disease treatment complicated by climate change

Evidence of these impacts is well-established. It has been corroborated by thousands of independent academic analyses, synthesis studies, and global programs led by governments, international organizations, and health systems.

Climate change can influence health outcomes in three ways: 1) the direct pathway of climate change impact on health; 2) an ecosystem-mediated pathway for health impacts; and 3) a societal systems/human institution-mediated pathway for health impacts.¹⁷ Co-emitted air pollution is treated separately to better account for the health impacts associated with the drivers of climate change and is classified in terms of sources that contribute to ambient air pollution versus those that contribute to household air pollution. Pathways may be linked to multiple outcomes; for example, extreme weather anomalies with shifts in temperature and precipitation affect vegetation and ultimately public health and agricultural outcomes.¹⁸ These pathways demonstrate the complexities that shape risk, the role of uncertainty in projecting impacts precisely, and the need for multi-disciplinary and often multi-sectoral approaches to effectively intervene.

Direct Pathway

This pathway refers to direct illness and death due to exposure to more frequent extreme weather events in which climate change may play a role. These include effects of high heat (including “heat exhaustion” and heat waves), droughts, floods, and storms.

Ecosystem-Mediated Pathway

This applies to illnesses and deaths due to events such as shifts in patterns of disease-carrying vertebrate animals, mosquitoes, and ticks, or increases in waterborne diseases caused by warmer conditions and increased precipitation and runoff, or slow-onset climate impacts such as salt-water intrusion from sea level rise. It also includes worsening air quality in general, and increased air pollution in particular, due to temperature increases and wildfires. There is also potential for increase of AMR in some bacteria as a result of increased temperatures.

Societal Systems/Human Institutions-Mediated Pathway

This includes death and sickness from altered systems created by humans. These include agricultural production and distribution, urban environments and food insecurity, stress and undernutrition, numerous challenges related to massive population displacement, damage to healthcare infrastructure and services, economic losses due to widespread “heat exhaustion” impacts on the workforce, or other environmental stressors, and different forms of non-economic loss and damage.

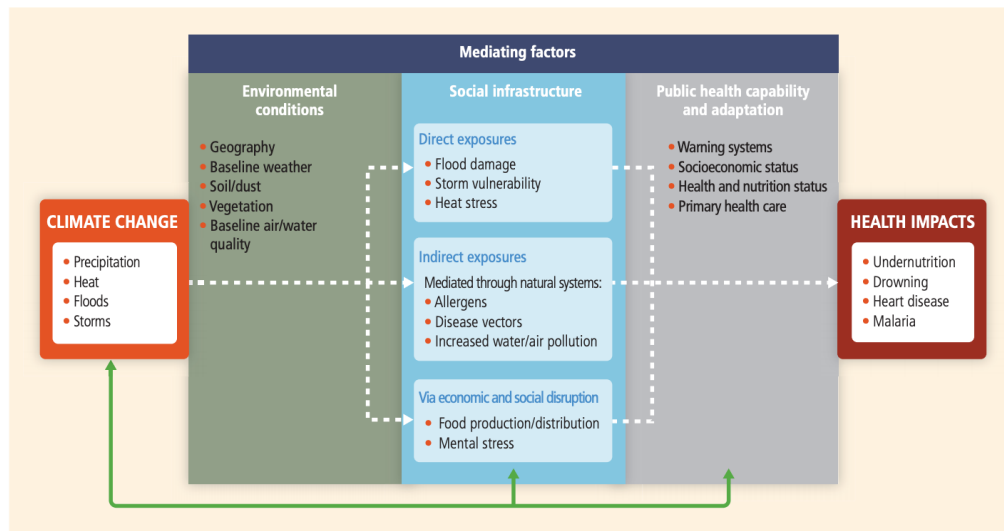


Figure 1. Pathways to health outcomes linked to climate change. Attribution: IPCC

The three pathways and a variety of corresponding health outcomes indicate why a multi-sectoral approach is needed – and why halting anthropogenic climate change is far optimal compared to relying on response to its diverse effects. Unfortunately, despite strong evidence of negative consequences, including impact on health, many countries and sectors have *increased* greenhouse gas emissions in recent years.¹²

Quantification of Burden

Across the different pathways above, no single burden of disease estimate aggregates climate changed-associated illness and death comprehensively. As a result, the full scope of disease burden is undoubtedly under-estimated, and the climate crisis can be expected to have dire and ultimately existential threats and consequences if unabated. However, attribution of impacts linked fully or partially to climate change is increasingly clear. For example, studies published between 2015-2020 indicated a role of climate change in 76 floods, droughts, storms, and temperature anomalies.¹²

Heat. By the end of this century, the yearly burden of temperature-related mortality alone is projected to nearly match the current impact of obesity: reaching 4.6 million annual deaths, or 6th highest on the 2017 Global Burden of Disease risk factor list.¹⁹ This so-called “mortality cost of carbon” is even more striking when considering that it will be far higher once the wider health impacts of climate change are accounted for – including indirect impacts of water and food-related security from increased temperatures. As we approach 2100, impacts will grow rapidly; heat-related problems are projected to potentially result in about 65,000 additional deaths in 2030 among those aged 65 and over, without adaptation.²⁰ Even if warming stays within 1.5°C, 42% of the population will be exposed to extreme heat by 2050; if climate targets fail to be met and temperature change reaches 3°C, extreme heat exposure will affect 86% of the population.²¹

Box 1. Climate-change related increases in disease and pests put food production at risk. While locust invasions have multiple causes, climate change is likely to increase the frequency of invasions and extent of their damages in some regions through hotter and wetter conditions that support locust egg survival and breeding.²² For example, the scale of the 2020 desert locust swarm in East Africa is thought to be at least partially linked to Tropical Cyclone Gati in Somalia, which caused unseasonal breeding.

Nutrition and Food Security. An additional 7.5 million children are expected to be stunted by 2030, 4 million of whom are expected to be affected by severe stunting (a 4% increase). A WHO report estimates this number will increase with climate change to 10 million additional children stunted by 2050 compared to a 1961-1990 baseline climate. Due to crop losses, the impact of climate change on food prices in Africa could be as much as 12% higher in 2030 and 70% greater by 2080 – a crippling blow to those nations where food consumption by the poorest households amounts to over 60% of total spending. Food production may be threatened by a range of direct and indirect effects (Box 1). Ocean warming and acidification due to elevated levels of CO₂ is contributing to collapsing fish stocks in number and size. This reduction in marine biomass threatens the food security of the approximately 3 billion people that derive a portion of their animal protein from it.²³

Infectious diseases. Climate impacts could increase the burden of diarrhea by up to 10% by 2030 in susceptible regions like Southeast Asia. At the global level, warming of 2-3°C is estimated to increase the number of people at risk for malaria by up to 5%, or more than 150 million people.²⁴ Impacts will likely be gendered, as seen in rural livestock-based economies where women are two-thirds (400 million) of low-income livestock keepers and have heightened exposure to zoonotic infections. Disease impacts will affect other species too; for example, increased environmental temperatures allow the parasite that causes Theileriosis (East Coast Fever) in livestock to become infective more rapidly, meaning the speed of transmission to livestock may increase once the tick vector is attached.²⁵ A similar temperature-dependent trend has been reported for development of the parasite responsible for malaria; already the most common vector-borne disease globally, net warming may have implications for malaria transmission beyond shifting geographic ranges of mosquitos.²⁶ The threat of disease introduction and spread is evident, as seen from the severity of the Zika virus epidemic in the Americas and detection in 86 countries. Even for disease epidemics not directly caused by climate change, it can hinder control measures and leave populations vulnerable to future risks and impacts (Box 2).

Box 2. COVID-19 and intersections with the climate-health crisis

While climate change has not been identified as a direct contributor to the emergence of COVID-19, several aspects of pandemic risk and response intersect with the drivers and impacts of climate change.

Drivers. Deforestation trends were bleak overall during the first year of the pandemic, with a 12% increase in the rate of deforestation of primary forest in the tropics. With budget cuts and loss of tourist revenue, protected areas (PAs) have been impacted, especially in Africa, where over half of PAs have had to reduce or stop their anti-poaching initiatives or field patrols and outreach efforts.²⁷ Conditions are ripe for illegal wildlife hunting as well as other activities contributing to environmental degradation including illegal mining.^{28,29} Partially as a result of measures to control spread of COVID-19, demand for single-use plastics, most based in petrochemicals linked to fossil fuel-heavy production and disposal, has increased.

Impacts. There is evidence that long-term exposure to co-emitted fine particulate air pollution (PM_{2.5}) is linked to increased risk of dying from COVID-19. Extreme weather events, ranging from flooding to wildfires, left communities displaced and in some cases unable to follow distancing and WASH procedures necessary for stemming transmission. An estimated 50 million people have been affected by both climate-related disasters and the pandemic.³⁰ Tragically, an estimated 115,000 healthcare workers have lost their lives in the pandemic, leaving behind a workforce gap that means already-understaffed health systems will be even less prepared to take on climate impacts.

Respiratory disease. Not all climate-related health impacts of concern will occur in the future. The emissions that drive climate change are largely co-emitted by the same sources that are currently responsible for more than 7 million premature deaths each year due to ambient and household air pollution. A separate study suggests the impact could be even higher, attributing 18% of global deaths in 2018 to exposure to particulate matter from fossil fuel emissions.³¹ Millions more suffer from related diseases, including pneumonia (particularly affecting children), lung cancer, cardiovascular disease,

stroke, and chronic obstructive pulmonary diseases. The increasing frequency and extent of large-scale droughts, high temperatures, and large-scale fires will only increase respiratory disease deaths.

At the country level, impacts of climate change and air pollution become more concrete (see, for example, Health and Climate Change Country Profiles 2015 and 2021, and Table 1).³² Improving precision of country-level impacts will help guide targeted measures, in addition to generic measures likely to be relevant across geographies.

Table 1. Country and regional examples, illustrating the variety of anticipated health impacts of climate change and air pollution, which can help inform mitigation and adaptation opportunities for systems and self-protection

Country	Examples of Anticipated Impacts (High Emissions, Business-as-Usual Scenario, by 2100 unless otherwise specified)
Brazil	<ul style="list-style-type: none"> • Mean annual temperature is projected to rise by about 5.4°C on average, with consequent rise in mortality in persons 65+ and productivity loss of 12% in heavy labor industries. • Heatwave conditions will increase to 265 of days of the year, up from only 10 in 1990. • Extreme weather is expected to lengthen by five days, with approximately 618,000 people to be affected by sea level rise, and additional impact from inland risk flooding. • 168 million people (82% of the country’s current population) will face risk of malaria by 2070.
Germany	<ul style="list-style-type: none"> • Mean annual temperature is projected to rise by about 5°C by 2100. • Heat-related impacts vary by region of the country. Western Germany in particular has recorded greater ischemic heart disease related to periods of heat exposure, and by the end of the century extreme heat is expected to result in 8,500 excess deaths each year. • The emergence of Schmallenberg virus, first detected in Germany in 2011 and subsequently spreading and now endemic in several areas of Western Europe, is linked to production losses in cattle, sheep, and goats. The disease is transmitted by midges whose activity is temperature-limited; main periods of transmission are currently restricted to non-winter months but could lengthen under predicted temperature increases.
Southeast Asia	<ul style="list-style-type: none"> • The burning of biomass in Indonesian forests and peatlands is a notable contributor to global emission levels and an active concern for populations in the region. Worsened air quality and exposure to fine particulate matter is associated with respiratory and cardiovascular diseases. If current trends of peatland draining and forest clearing continue, a conservative estimate of 36,000 excess adult deaths per year can be expected across Indonesia, Malaysia, and Singapore, with total excess regional mortality reaching over 80,000 annual deaths.

Economic Impacts of Climate-Health Threats

The impacts of climate change threaten to pull over 100 million people back into extreme poverty by 2030,²⁴ reversing hard-earned development gains. Many of these cases can be linked to negative health outcomes. Those already least able to manage the burden have limited access to self-protection measures and safety nets necessary to cope with new or increased exposures and burden. One major concern is the predicted increase in mass migration and displacement and the associated health consequences for vulnerable populations.

Forecasts suggest that by 2030 an additional 250,000 deaths per year will occur from heat exposure, undernutrition, malaria, and diarrheal disease due to climate change. These estimates are well-known to be conservative and do not include all climate-sensitive health impacts, e.g., pollution, injuries, non-malaria infectious disease, and others for which projection data is lacking.²⁰ Cancer risk is also likely to increase as a result of climate change-related exposures; but coping with this increase will be challenged by health system disruptions that could consequently affect cancer control measures.³³

This additional burden of disease comes with a significant economic global and local impact. One study estimates the global additional costs associated with climate change-related cases of just three sets of diseases—malaria, diarrheal diseases, and malnutrition—to be US\$4–12 billion in 2030 under the business-as-usual scenario.³⁴ It is crucial to keep in mind that the cost of disease is *in addition to* the expected damages in health-determining sectors such as agriculture, water, and sanitation, underlining the serious economic toll to be expected.

Separate work suggests there are also significant costs associated with disaster-related health impacts. Although little research has been undertaken for developing countries, it has been estimated that climate-related disasters have already caused US\$14 billion in health-related costs over a 10-year period in the US alone.³⁵ Other research has estimated an 11-20% decrease in labor productivity losses due to excess heat (correlating to health stress) in heat-prone regions such as Asia and the Caribbean by 2080.³⁶ If avoided, these aggregate health costs, along with other benefits of limiting warming to 2°C, would yield economic savings far greater than the US\$1.5–2 billion per year for health sector adaptation.³⁷

The economic costs associated with the air pollution-related burden of disease are also considerable. A study by the Organization for Economic Co-operation and Development found that air pollution illnesses and mortalities correspond to US\$1.7 trillion of lost output annually in OECD countries, US\$1.4 trillion in China, and US\$500 billion in India.³⁸ Globally, air pollution accounts for \$5.11 trillion in welfare losses each year.³⁹

Climate mitigation can have health co-benefits. Reducing emissions of greenhouse gases through better and more active transport can be good for cardiovascular and respiratory health; more sustainable food and energy-use can result in better nutrition and cleaner air and water quality. Better nutrition in childhood will reduce the risk of NCDs (which are responsible for 70% of mortality worldwide) as an adult.⁴⁰ Climate mitigation scenarios have estimated global average health co-benefits of reduced air pollution between approximately US\$60-US\$380 per ton of CO₂ avoided – a clear benefit:cost ratio when compared to the global average carbon price of \$2 per ton (though higher in some high-income countries).^{41,42}

Furthermore, a broad cost comparison found that, when factoring in the benefits of mitigation of zoonotic pandemics and curbing greenhouse gas emissions via reduced deforestation, the net prevention costs would range from \$18-\$27 billion per year – a mere fraction of the economic impact of the COVID-19 pandemic, which has been estimated at over \$10 trillion in output losses in addition to global response costs.^{43,44}

Multiple, Interlinked Threats

Antimicrobial resistance is projected to be a leading cause of death by 2050. While usually addressed as separate development priorities, there are important areas of overlap for climate change and antimicrobial resistance (AMR), where resources can be optimized to improve health outcomes. Climate change is already shifting the range of host species and pathogens, with resulting increases in incidence of some vector-borne diseases (such as tick-borne encephalitis in Europe and scrub typhus across much of Asia). This will result in a rising demand for antimicrobials to treat these climate-sensitive diseases. The threats and impacts are not limited to terrestrial diseases alone. In aquatic ecosystems, effects of climate change may increase conditions supportive of some bacterial contamination and increased fish mortality, particularly in tropical regions, thereby requiring increased antibiotic use. Expanding aquaculture production is a priority for development, to reduce pressure on wild-caught fish stocks and to meet rising nutrient demands with low-carbon production systems.⁴⁵ Similarly, expanding antimicrobial use, often with limited evidence of effectiveness, in the agricultural sector has led to dissemination of antibiotics and their related residues throughout the environment. For example, the treatment of citrus greening in the United States with antibiotics has led to widespread spraying of human-relevant tetracyclines, with little consideration of the trade-offs or downstream risks to human health.⁴⁶ Flooding can further spread pathogens, antimicrobial residues, and antimicrobial-resistant genes from agriculture and aquaculture

production systems, municipal water sources, and waste management facilities. While the epidemiological importance of some of these pathways have been poorly established in terms of precise risks and impacts, the impact of AMR grows every day, with attention to environmental aspects of AMR risks increasingly recognized as a priority.⁴⁷ This points to the importance of infection prevention and control to both mitigate and adapt to climate change-exacerbated risks.

The imperative for disease prevention is strengthened when considering the status of infection prevention and control (IPC) at healthcare facilities and the potential added strain of climate effects on already-weak healthcare systems. Unfortunately, approximately 10% of patients acquire healthcare-associated infections in the process of receiving care. Where IPC strategies are available, they are often poorly resourced and operationalized.⁴⁸ In fact, a quarter of the world's health facilities (covering 1.8 billion people) lack basic water resources – which is likely to be exacerbated periodically or permanently by increasing water scarcity in some regions due to climate and other changes.⁴⁹ Many healthcare and other settings also face inadequate waste management, which contributes to emissions from burning and environmental contamination. Exposure to hazardous waste is also linked to negative health effects.⁵⁰ While health impacts of climate change make universal health coverage (UHC) all the more necessary, the increased burden of disease will increase healthcare system demand and cost. While COVID-19 has increased awareness and access to IPC measures, reliance on health systems to continue to prioritize IPC measures long-term requires financial, capacity, and operational commitments. At the same time, there is increasing recognition of the need for IPC in community settings for prevention and containment at source, and extending practices into animal health sectors.

Risk Reduction to Promote Climate-Smart Healthcare

Countries are implementing a range of climate change mitigation and adaptation measures, some of which have direct benefits to health or are health sector-led. Sometimes these actions are undertaken with intent to improve health outcomes, while others are enacted predominantly to address climate change and have secondary health benefits. Either are preferable to no action at all, though a clear focus on health can be useful in building public understanding through relatability, emphasizing the critical nature of climate threats, and rallying policy support for further action.

While policies that explicitly recognize the links between climate change and health mostly focus on adaptation, there is an increasing number of national health systems also acknowledging their part in driving climate change and taking action to lead by example on decarbonization. England's National Health Service (NHS) took the lead in January 2020 as the first national health system to announce a commitment to reach net-zero emissions by 2040 (for emissions directly under its control), and has been followed by others at the national and subnational levels worldwide. Furthermore, in December 2020 Argentina became the first country in the world to include measures to estimate and reduce its national health system emissions in its updated Nationally Determined Contribution (NDC) under the Paris Agreement. A recently published study by the NGO Health Care Without Harm estimates that, by taking action simultaneously in its own operations and facilities, its supply chain and in the broader economy, the health sector's cumulative emissions reductions (in the period between 2014 and 2050) could amount to 44.8 gigatons of CO₂eq -equivalent to the entire world economy's GHG emissions in 2017.⁵¹

Change is also happening at the facility level worldwide, with a growing number of hospitals and health centers joining global decarbonization efforts. As of October 2021, 45 health care institutions representing the interests of more than 3,200 hospitals and health centers in 18 countries had joined the UNFCCC-backed "Race to Zero" campaign, pledging to reach net-zero emissions by 2050 or earlier.

At the national level, there are many interventions to address climate-sensitive health threats that can bolster solutions and enable countries to become true champions in building health protections against climate change, while also reducing health care's own climate footprint. Below are some examples drawn from actual country-programming. Many of these are often enacted in parallel and result in further action

from other in-country actors, such as NGOs, university researchers, companies, and innovators who build on national-level leadership for continued health and climate action.

National-Level Climate Change and Health Specific Interventions

- National and subnational climate and health assessments
- Climate-health action plans
- Integration and adoption of climate-health considerations into other health and environmental policies/programming
- Funding for climate-health research and workforce development (universities, NGOs)
- Funding for climate-health interventions (NGOs, private sector, entrepreneurs)
- Funding for international climate and health programs (e.g. WHO, WMO, development institutions)
- Participation in international frameworks and alliances
- Support to health systems anticipating climate-health threats

There are many examples of each of these that can be found globally. At present, a worldwide climate change and health data portal is currently being built by the joint office of WHO-WMO. This website will host considerable country-level information and aims to be a definitive source for accessing replicable climate and health programming material.

Drawing on research and funding established by these critical government programs and precedents are local and facility-level actions, which address climate change and health in often immediate ways. This local work brings national policies down to a level that is relevant to communities, businesses, and individuals. Below are some examples of national, subnational and facility-level action on climate and air pollution.

Brazil: Sustainability Planning

Albert Einstein Hospital in Sao Paulo, Brazil, developed and implemented a sustainability master plan in 2010 with initiatives that cut annual greenhouse gas emissions by 2,000 metric tons of CO₂, or 41%.

South Africa: Hospital Efficiency Measures

The Western Cape government has eliminated the coal- and oil-fired boilers at nearly all its 53 hospitals. Annual savings from Lentegur hospital's laundry efficiency measures alone include more than 19 million liters of water, over 550 metric tons of CO₂, and at least US\$62,000 in costs. Extrapolating for all Western Cape government hospitals, the savings would add up to US\$3.3 million annually.

Germany: Tracking Infectious Disease Threats

The national surveillance system monitors several climate-sensitive diseases or pathogens including cholera, typhoid fever and hantavirus, as well as foodborne and waterborne infectious diseases such as *Campylobacter* spp.

Kenya and Tanzania: Disease Forecasting for Disaster Risk Reduction

The International Federation of Red Cross and Red Crescent (IFRC) Climate Centre has invested heavily in its "Early Warning > Early Action" campaign and in 2012 piloted a health risk management project that focused on deploying early warning systems to reduce the burden of diarrheal disease in Kenya and Tanzania. A similar approach is also being applied for dengue fever in Indonesia and Vietnam.

United Kingdom: Leading a Net Zero Health System

The National Health Service (NHS) Net Zero strategy commits the NHS to reaching net zero greenhouse gas emissions from its buildings, services, and vehicles by 2040 – on the way to Britain's overall pledge of reaching net zero by 2050. The strategy builds on significant progress in reducing the carbon footprint of the NHS since 1990, and will mainstream decarbonization throughout supply chains and operations, ranging from 40 new hospitals to digital options to reduce patient travel.

Mexico: Safe, Healthy and Efficient Hospitals

In Mexico City, which has historically had poor air quality, the medical specialties tower of the Manuel Gea González General Hospital reduces pollution by actively removing smog from the surrounding air. The hospital is surrounded by a giant, honeycomb-like screen that is coated with titanium dioxide, which converts smog into benign chemicals upon contact. The screen also blocks sunlight, which reduces the amount of energy it takes to cool the air within the hospital.

India: Innovative Heat Wave Early Warning System and Action Plan

Ahmedabad is a growing urban center of 7 million people in Gujarat state, western India. During an extreme heat wave in 2010, the city registered 1,344 additional deaths. Following this event, the Ahmedabad municipal corporation and a coalition of national and international experts came together in 2013 to develop and implement an early warning system and the first Heat Action Plan (HAP) for a city in India. Technologies are also being tested to reduce emissions from brick kiln making, which is the 3rd-largest industrial source of coal emissions in the country and a major source of air pollution. This effort involves an integrated approach to improve human and animal health, addressing occupational health conditions for kiln workers and the donkeys, mules and horses that carry heavy loads in high heat, often without sufficient water, shade, or rest.⁵²

Nigeria: Tackling Short-Lived Climate Pollutants

In Nigeria, short-lived climate pollutants (SLCPs) pose a major threat to human health and act as significant climate warmers. In 2017 SLCPs (resulting from household energy use, transport, agriculture, industry, and waste among other sectors) were responsible for 114,000 premature deaths, over half in children under five. The Nigerian government has outlined 22 mitigation measures across eight sectors, including replacing all kerosene lighting with solar lamps by 2022 and reducing crop residue burning by 50% and generating 30% of all electricity using renewable energy by 2030.⁵³

Poland: Phasing Out Coal Production

Poland generates the majority of its electricity from coal. In 2020, motivated by the EU's cap-and-trade system and impacts of COVID-19 on energy demands and the health of those in the mining sector, Poland updated its energy plan to phase out coal production by 2049.⁵⁴ With costs from ambient air pollution reaching an estimated 6.4-8.3% of the country's 2016 GDP, Poland will see numerous co-benefits from shifting away from coal reliance.^{55,56}

United States: Prioritizing Health Equity

The United States (U.S.) Department of Health and Human Services is establishing an Office of Climate Change and Health Equity (OCCHE). The OCCHE seeks to protect those most vulnerable to health effects of climate change, identifying at-risk communities for exposures to climate hazards, addressing disparities, and building in mitigation, adaptation, and resilience measures with communities and the health care sector as a whole.⁵⁷

These promising initiatives are an important foundation, and require mass upscaling at all levels, including for on-the-ground implementation. Crucially, in addition to health sector leadership itself, the expertise and leadership of other sectors is also relevant for climate and health action and outcomes – for example, ecologists in landscape planning and anthropologists in the design of behavior change campaigns (Table 2).

Table 2. Examples of disease prevention and response measures relevant to climate change and air pollution, targeted to most relevant scale. National, regional and global measures rely on having systems in place, and can be upscaled, whereas individual/community interventions can be considered as self-protection. Several measures can contribute to both prevention and response and be applied at multiple levels.

Scale	Prevention	Response
<i>Individual and community, including facility-level</i>	<ul style="list-style-type: none"> • Exposure reduction (e.g. avoiding working or recreation in high-risk settings or times) • Hand hygiene and other WASH behavior change • Barrier methods (e.g. personal protective equipment, mosquito nets) • Community or facility-based WASH measures (e.g. waste management) • Utilization of public health services for prevention (e.g. vaccination) • Enforcement of International Labour Organization best practice around occupational health and health & safety 	<ul style="list-style-type: none"> • Nature-based solutions to increase resilience (e.g. cultivating local varieties of drought-resistant crops, urban cooling) • Utilization of healthcare services for early detection and effective treatment
<i>National/regional</i>	<ul style="list-style-type: none"> • Inclusion of climate-sensitive disease risks in National Action Plans for Health Security • Risk reduction for high-consequence disease interfaces and pathways • Early warning systems and access to prevention and control strategies (e.g. human and animal vaccine banks) • WASH infrastructure • Comprehensive risk/impact assessment and safeguard requirements • Land use planning to avoid greenhouse gas emissions, maintain carbon sequestration and other health-relevant ecosystem services, and reduce possible threats to health and wellbeing 	<ul style="list-style-type: none"> • Vulnerability assessments • National adaptation plans (health-specific and health-mainstreamed) • Public health and healthcare system reporting of climate-sensitive diseases in humans and animals • Climate-smart healthcare investments to withstand increased demand and extreme weather events • WASH infrastructure • Land use planning for resilience against climate change impacts
<i>Global</i>	<ul style="list-style-type: none"> • Adoption of ambitious NDCs that collectively allow for the achievement of the goals of the Paris Agreement, particularly the limitation of global temperature rise to 1.5°C before 2100 • Deliver on international climate commitments in a measurable and transparent way, particularly commitments to halve emissions by 2030 and reaching net-zero by 2050 • Shift to disease prevention stance 	<ul style="list-style-type: none"> • Monitoring and rapid response • Expansion of health workforce

Cost of Inaction/Missed Opportunities

As of mid-October 2021, the COVID-19 pandemic has resulted in over 236 million confirmed cases, with over 4.8 million reported deaths.⁵⁸ Excess mortality, including from disrupted healthcare services for other diseases in addition to COVID-19 itself (and minus the reductions in deaths from other causes of deaths declining as a result of behavior change during the pandemic), has been estimated at 6.9 million deaths up to early May 2021.⁵⁹ A range of extreme weather events have pushed communities into emergency situations during the pandemic that compromise control measures and increase vulnerability, in some cases worsening COVID-19 outcomes. Yet the impact of the COVID-19 tragedy is overshadowed by an

existing burden of disease from unhealthy environments. As of 2012, environmental factors contributed to an estimated 12.6 million deaths each year, or a fourth of total deaths globally, linked to more than 100 disease and injuries – while still likely under-estimated by not comprehensively linking some epidemics and other health impacts to environmental risks.⁶⁰ In addition to the COVID-19 pandemic, localized and regional epidemics cause significant human and animal health and economic outcomes; dengue in Southeast Asia, tick-borne encephalitis in Europe, and Rift Valley fever in Southern and Eastern Africa are just some recent examples. The limited present ability to stop outbreaks at their source, in some cases leading to increasing resistance to treatment and insecticide, means effective response to some health impacts of climate change is likely to be hampered.

The drivers of climate change, and climate-mediated disease risks, originate from many sectors, namely energy, construction, transportation, and agriculture. Globally, the healthcare sector itself contributes an estimated 4.4% of global net emissions, even as many countries face under-developed healthcare infrastructure and access that will require expanded energy utilization to adequately serve even current health needs.⁵¹ Therefore, in addition to integrating resilience considerations, the necessary growth of the health sector worldwide must be deliberately designed to reduce emissions wherever possible; otherwise, if it continues along its current trajectory, healthcare’s climate footprint could more than triple by 2050.⁶¹

At the same time, the scale of environmental change over recent decades – and ongoing to meet growing resource demands- means that the very ecosystem services that are fundamental to health and wellbeing are being compromised at an alarming pace (Table 3). On our current trajectory, we face growing missed opportunities to salvage disease prevention, at the risk of resource-intensive response.

Table 3. Examples of ecological degradation and what that means for climate change and health.

Issue	Scale	Implications for Climate	Implications for Health
Forest loss	Since 1990, 420 million hectares of forest have been lost to human activity. From 2019 to 2020 the tropics faced a 12% increase in the rate of deforestation of primary forest	Direct emissions from destroyed carbon sinks; loss of carbon sequestration and storage resources; may be replaced with emission-generating activities; soil erosion	Reduction of numerous biodiversity and ecosystem services including preventing soil erosion and flood mitigation, air and water filtration, pollination, and resources for food, medicine, goods and services, among others. Habitat loss may lead to some wildlife species shifting their range, living in closer proximity (and higher densities) to human settlements with potential for disease transmission between humans and domestic animals
Mangrove destruction	Between 2000 and 2016, loss of 3,400 square kilometers (~2% of the world’s total mangrove area), and several high-value conservation mangrove areas remain without legal protection and thus are vulnerable to habitat conversion	Direct emissions from destroyed carbon sinks; loss of carbon sequestration and storage resources; disruption of interconnected root systems increases soil erosion and diminishes coastal protection services	Degradation of soil and water quality; loss of resources for food, medicine, goods and services; loss of biodiversity supportive of pollination, pest control, and other benefits
Coral reef degradation	Over 60% under direct and immediate threat from	Loss of coastal protection (intact reef systems shield the	Loss of marine food webs and associated nutrition resources

	human impact as of 2011 (expected to be 90% by 2030)	adjacent land from ocean waves and mitigate storm surges damage, providing coastal communities with protection from hurricanes and coastal erosion)	and livelihoods; degradation of water quality; injuries
Wildfires	Increasing in frequency; shifting to areas with historically low fire activity; in the past forty years, the length of fires has increased across a fourth of the world's vegetated areas	Direct emissions (including methane) and loss of carbon sequestration resources; soil erosion that increases vulnerability to disaster impacts from flash floods	Degradation of water quality and impacts on water security; injuries; respiratory impacts from smoke plumes (may extend thousands of miles from source fires); fear, depression and anxiety; resulting risks and impacts from extreme flooding

While countries are investing in some disease prevention, detection, and response capacities, these are not yet systematically connected to climate action on a wide scale, particularly for the upstream drivers such as deforestation. There is a clear economic imperative to optimize resources for health and environmental protection co-benefits. In fact, if correctly pursued, climate policy could yield trillions of dollars in global health benefits per year from carbon mitigation acting on air pollution by the end of the century.⁶² However, the limited inclusion of human health considerations in climate policies to date result in hidden externalities that can generally be expected to be magnitudes higher in cost for response compared to what would be required for prevention.

Connecting the Human Health Impacts of Climate Change to Animals and the Environment

As noted above, the health impacts of climate change occur through various pathways. These are mediated through natural and built ecosystems involving a multitude of environmental and biological determinants. Infectious diseases, for example, can result from changes in temperature, humidity, and often host species distribution; malnutrition is correlated with weather and agricultural output; and heat stress typically aligns with urbanization or labor. Viewing these health challenges merely through the lens of global-scale climate change therefore misses important ecosystem interactions – and nature-based solutions* which offer cost-effective alternatives to the response-focused, resource-intensive business-as-usual approach. Fortunately, there are frameworks which focus on these important environmental health relationships and which can be useful in establishing avenues for climate action.

One Health, for example, is perhaps the best-known model for understanding and acting on these relationships, and is increasingly embraced by governments, intergovernmental agencies, academic institutions, and civil society. Broadly, it can be defined as “collaborative efforts of multiple disciplines working locally, nationally and globally to attain optimal health for people, animals and our environment”.⁶³ It includes the proactive involvement of human medicine, veterinary medicine, public health, and environmental health sciences to collectively improve health for people, domestic animals, wildlife, and ecosystems. The approach allows for the calculation of costs and benefits across a wider array of outcome and sectors, ideally in pursuit of achieving multiple bottom lines.

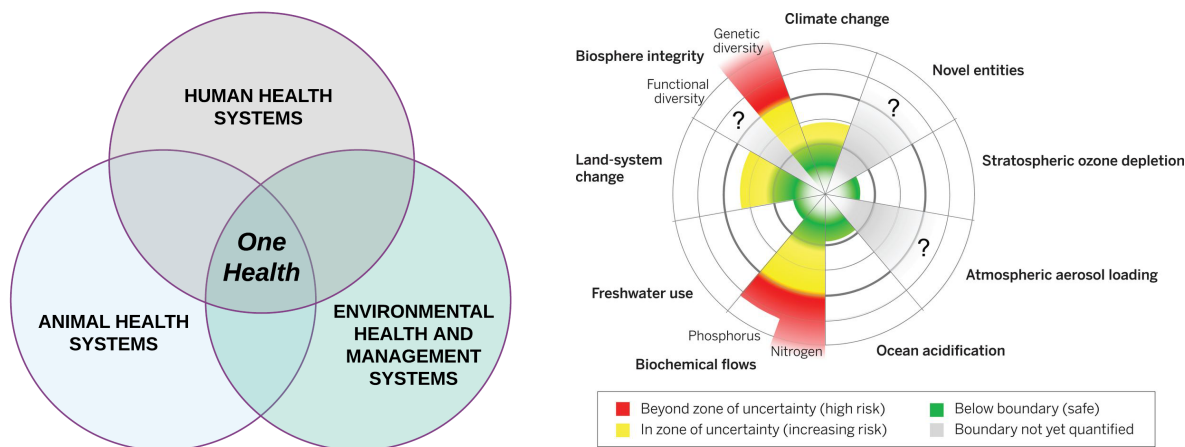
Planetary Health is another important, and related, model for understanding health and environmental relationships, characterizing health risks associated with rapidly accelerating, anthropogenic

*Nature-based solutions are defined as “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.”

environmental change that threatens to exceed the safe operating space for humanity ('planetary boundaries').^{64,65} Here, there are a range of changes with the potential to significantly impact human health to consider, which have been called the 'triple planetary crisis' of climate change, nature and biodiversity loss, and pollution and waste.⁶⁶ These relate to fishery collapse, land-use change, urbanization, ocean acidification, sea temperature and level increases, freshwater scarcity, and others. Accordingly, holistic interventions are required to safeguard the future health of both people and planet, regardless of the particular environmental or health threat encountered. This model is therefore particularly useful in understanding global-level impact of human action, while lining up climate health impacts alongside other environmental health threats, fostering a cross-pollination of solutions for transdisciplinary positive impact.

Regardless of terminology, these models (Figure 2) articulate the value of working across sectors to understand and act on the drivers and impacts of climate change and their consequences for health as well as wider wellbeing and economies. The World Bank developed a One Health Operational Framework 2018,⁶⁷ and a Global Plan of Action on One Health is currently in development by intergovernmental agencies. Several countries have recently established national One Health coordination platforms that will be integral to COVID-19 recovery and prevention of future epidemics. A major challenge to date remains limited capacity and resourcing of the environment sector to be fully represented and contributing to prioritization and implementation of One Health initiatives; as a result, much of the focus falls to disease detection and effective response, rather than intervening on root causes to avoid risk. Additionally, with siloed programs even within public health institutions, climate change is often viewed as 'outside of' a health security focus – despite climate change contributing to disease risks and climate action being necessary to move toward disease prevention. Design and implementation of One Health investments should be proactive in assessing and managing climate-sensitive health links, offering a way to more fully anticipate risks and curtail burden throughout global, national, and subnational plans, policies and programs.

Figure 2. Models for One Health (left) and planetary boundaries (the basis of Planetary Health science) (right).
Source: Berthe et al. 2018 (left), and Steffen et al. 2015 (right).



The 2030 Agenda includes 17 Sustainable Development Goals (SDGs). Goal 13 calls for urgent action to combat climate change and its impacts, while Goal 3 aims to ensure healthy lives and promote well-being. Virtually every other goal includes some dimension that touches upon health and/or climate, underscoring the relevance of integrated systems perspective across environmental and health spheres, which is at the heart of the One Health and Planetary Health approaches. These possible trade-offs, and co-benefits, reinforce why multi-sectoral action and integrated approaches are required (Table 4).⁶⁸⁻⁷¹

Table 4. How climate change and health considerations cut across the SDGs. Adapted from World Bank 2017.⁷⁰

Sustainable Development Goal	Climate and Health Relevance
SDG 1: No Poverty: social protection measures; resource mobilization; equal rights to resources	Promotes resilience for those most vulnerable and least able to cope with health effects of climate change (lowest access to physical mobility, healthcare services, alternative livelihoods, infrastructure repairs and upgrades, food and water security, and occupational protections).
SDG 2: Zero Hunger: Improved cropping & livestock biosecurity practices; reliance on social networks, extension services sharing indigenous, traditional and local knowledge, seed banks; crop insurance	Water storage, to reduce impact of drought in crops, can increase water stagnation & vector transmitted diseases. Effects of climate, especially heat stress in agriculture workers, need to be taken into consideration. Climate-sensitive livestock diseases threaten animal health and production and potentially public health. Limited genetic/seed diversity makes societies more vulnerable to crop losses. Encourage switching agriculture production from health damaging cash crops such as tobacco to cash-generating healthier alternatives that support sustainable food systems. Reduced agricultural yields as a result of rising temperatures can aggravate food insecurity for millions, and therefore malnutrition and the diseases associated with it.
SDG 3: Good Health and wellbeing: universal health coverage; health financing; vaccine development; workforce development; early warning systems for disasters and health emergencies	Health protection and healthcare services will be crucial to reduce overall disease burden, including from climate change. Increased energy and other resource needs could increase emissions (and thus expansion should be climate-smart). Early warning systems should be inclusive of climate-sensitive disease risks for humans and animals.
SDG 4: Quality Education: Improved access to education, awareness raising & integration into education; gender equity in education	Education levels of populations, especially among women, are instrumental in disaster preparedness & response and reduction of vector & water transmitted diseases. Need for health workforce training to adequately assess and reduce climate-sensitive disease risks.
SDG 5: Gender Equality and Women's Empowerment: gender-specific risk communication; equal rights and access to economic resources; reproductive health rights and access to health services	Access to alternative livelihoods and workforce training will increase resilience and standing of women, including reduced exploitation and risk of violence. Potential for reduced exposure and impact to climate-sensitive diseases that disproportionately impact women and children, including in rural livestock-based economies.
SDG 6: Clean Water and Sanitation: sea walls, flood levees & coastal protection, early-warning & response systems; hazard & vulnerability mapping; floods and cyclones shelter; improvement of water quality, reducing pollution and increasing wastewater treatment; building codes/practices; watershed & reservoir management, climate resilient water safety plans, diversifying water resources municipal services (water & sanitation), water and fecal waste effluent quality control	Improved WASH infrastructure may require increased energy generation. Improved water quality and sanitation will mostly reduce climate-sensitive disease, though water capture and storage may increase vector-transmitted diseases. Increasing water temperatures likely to increase bacterial contamination and need for antimicrobial use. Climate change is likely to increase water scarcity and reduce access to potable water, which can trigger physical ailments and diseases associated with dehydration and the intake of polluted water.
SDG 7: Affordable and Clean Energy: clean renewable energy generation & resilient distribution, universal access to clean energy,	Clean energy reduces climate-sensitive impacts, through reduction in indoor & outdoor air pollution. More reliable energy access will increase quality of healthcare and health-supporting services (e.g. laboratory, water treatment, vaccine cold chains), though a low-

renewable energy, incentives for energy efficiency	carbon transition will require climate-smart commitments from donors and the healthcare sector.
SDG 8: Decent Work and Economic Growth: occupational protections; efficient, resilient industries	Extreme heat and vector-borne diseases likely to affect outdoor worker health and productivity of those most vulnerable to exposures. Clean energy and new resilient infrastructure (especially green and blue) industries likely to create significant new job growth.
SDG 9: Industry, Innovation, and Infrastructure: transport and road infrastructure improvements, clean rapid transport systems (e.g. trains and trams), transport corridors, waterways, ports	Mostly reduces impacts through increased connectivity and reduction of pollution, though can have negative impact if its infrastructure damages fragile ecosystems. Can guide development to “safer areas”. Health sector growth must be integrated into urban planning so that healthcare facilities are well connected to low-carbon public means of transportation. Developing transport infrastructure, as well as telemedicine infrastructure, is also crucial for health services to reach remote communities.
SDG 10: Reduced Inequalities: reduction of income disparities; equal opportunities; improved living conditions; facilitated safe migration and mobility of people; regulation and monitoring of financial markets	More equitable distribution of resources increases access to safety nets and improves resilience to cope with disease burden. Transparency and safeguards must be in place to mitigate harmful externalities that result from sectors driving climate change, biodiversity loss, and disease risk. Proactive policies to facilitate orderly and safe migration are crucial to face health-related challenges of the massive human displacements expected to be triggered by climate impacts.
SDG 11: Sustainable Cities and Communities: urban planning & upgrading programs; air quality standards, building standards (resilience & energy efficiency), active transport, heat reflecting surfaces, maintaining wetlands & urban green spaces; infrastructure & services; managing development in flood prone and other high risk areas; land zoning laws; easement areas, storm and drain clearance, waste management	Climate-smart urban planning and improvements can reduce climate-sensitive impacts, through reduction in outdoor air pollution and health island effect, and drainage reduces vector transmitted diseases as well as avoiding establishment of communities in disaster/extreme event prone zones. WASH infrastructure reduces spread of disease (depending on the model, waste management can increase or decrease -or at least maintain- vector transmitted diseases at times in different areas of a city). Wetlands in urban and peri-urban areas are likely to increase vector-transmitted diseases, reinforcing importance of planned urbanization and assessment of risks of encroachment into wild areas.
SDG 12: Responsible Consumption and Production: phase out fossil fuel subsidies; sustainable use of resources; halving global food waste; waste management and reduction; optimized human and animal health interventions (e.g. multi-disease vaccines)	Will promote more efficient and equitable access for a number of health-related outcomes, including for nutrition and water security, and reduce unnecessary emissions, waste, and pollution. Potential risk of disruptions in healthcare systems highly dependent on consumables. Safe disposal of hazardous waste from healthcare settings can reduce emissions and harmful exposures.
SDG 13: Climate Action: reduced emissions, air quality standards; national & sub-national adaptation plans; climate services; participatory scenario development; integrated disaster assessments	Climate action can reduce the extent of climate change, avoiding/reducing health impacts, and support adaptation to and resilience against impacts. As Environment authorities often lead national adaptation plans and Nationally Determined Contributions, close coordination with other authorities will be at the center of successful adaptation efforts.
SDG 14: Life Below Water: reduce marine pollution; control overfishing, aquaculture practices, reduction of stressors on ecosystems; protection of coastal and marine ecosystems	Rising temperature and acidification threatens marine resources used for food and medicinal compounds; Sea level rise threatens coastal communities with intensifying flooding and resulting injuries; salinity of low-lying areas used for food production threatens food insecurity (and malnutrition), and increase in fertilizer use can lead to runoff and harmful algal blooms.

<p>SDG 15: Life on Land: reduction of stressors on ecosystems and habitat fragmentation, maintenance of genetic biodiversity, restoring wetlands, ecological restoration; soil conservation; afforestation & reforestation including mangroves, assisted species migration and green infrastructure, payments for ecosystem services</p>	<p>Improved air quality management, and environmental services will generally reduce the impacts of climate-sensitive diseases. Maintenance of wetlands in urban and peri-urban zones is likely to increase vector-transmitted diseases. Keeping carbon and methane sinks (e.g. forests, permafrost) and other ecosystems and their services intact is crucial to mitigate risks.</p>
<p>SDG 16: Peace, Justice, and Strong Institutions: promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels</p>	<p>Institutions, including health and environment agencies, must be sufficiently capacitated and mandated to assess risks, enforce regulations, and intervene on climate and health risks through strengthening of policy and practice, including fighting corruption in industries and sectors contributing to greenhouse gas emissions.</p>
<p>SDG 17: Partnership for the Goals: strengthen the means of implementation and revitalize the global partnership for sustainable development</p>	<p>Action is needed at all levels to tackle climate change and health impacts – including multi-sectoral partnerships that optimize resources and consider long-term impacts.</p>

Research Priorities

Research agendas on climate and health have been well articulated by the World Health Organization and intergovernmental convenings such as the World Health Assembly, as well as other expert groups over the past two decades.⁷²⁻⁷⁴ These align with One Health and Planetary Health concepts and recognize the need for greater study of the links between health, and the environment, broadly. Some areas can be directly integrated into COVID-19 recovery architecture to increase capacity to assess and manage climate-sensitive threats:

- Explore nature-based options that are optimal for climate, biodiversity, socio-economic and health outcomes.** If not sufficiently assessed, planned, and managed, even well-intended climate-focused investments could drive disease risk, the establishment of invasive alien species, and other negative outcomes for biodiversity and health. Study of feedback loops in a target ecosystem could help identify and avoid unintended consequences as well as resource synergies. Research on ecological interventions may also inform new prevention options, such as restoration of food webs, water system management, safe introduction of predator species for vector-borne diseases, and landscape approaches that support disease regulation, removal of pollutants, and sustainable cooling strategies.⁷⁵ Nature's contribution to broader health and well-being (such as mental and spiritual health) should be emphasized.
- Link forecasting to a range of sectors to more fully incorporate early warning signals and proactively anticipate and mitigate downstream impacts.** As extreme weather events and epidemic and endemic disease threats become more common with the warming climate, disaster event forecasting must be improved and refined. Forecasts should be supported with evidence documenting the impacts of disasters, a changing climate, and other sources of environmental degradation on disease dynamics, food and water systems, and mental health, and the potential effectiveness of nature-based solutions, social safety nets, and preparedness.
- Improve precision and accessibility of forecasting systems to allow for greatest national and local utility of data streams and models.** While building on global architecture and insights that increasingly provide greater lead time for event warning, data collection at local levels can improve predictability and account for local variation, including for locally-important disease threats not tracked by global systems (e.g. endemic, neglected, and novel diseases) (see Box 3). Accessibility should

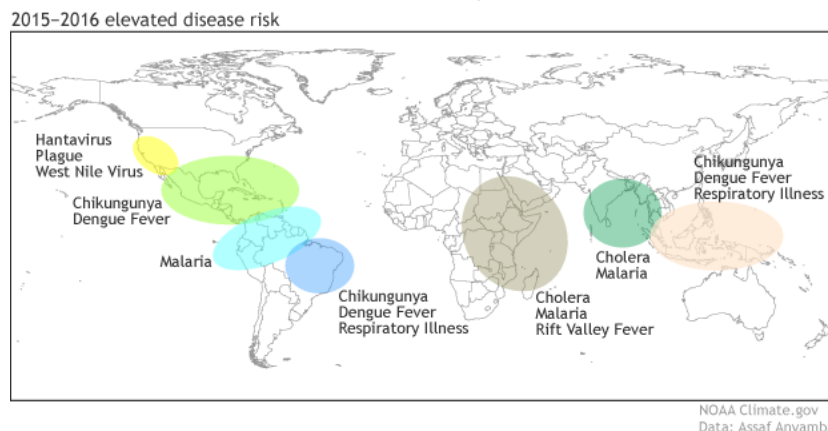
extend to capacity to interpret and act on results, with pathways to deliver early warning alerts where needed and mobilize effective responses.

- **Prioritize the study of behavior change and other social sciences to increase individual and community use of existing measures to reduce the health impact of climate change and air pollution, and build resilience**, such as uptake of safe practices to reduce contact with climate-sensitive disease vectors and the spread of communicable diseases (e.g. sexually-transmitted Zika virus), improved WASH compliance, and a transition to clean cookstoves.
- **Place greater focus on documenting and sufficiently coping with diverse impacts of climate change on the health and wellbeing of vulnerable communities**, including Indigenous Peoples and local communities, pastoralists and other mobile communities, women, migrant and displaced populations, youth and the elderly, including in selection and design of interventions sensitive to values, cultures, and priorities.

Box 3. Forecasting can inform prevention and preparedness.

Climate change is altering weather patterns, including year-to-year variability in the Earth’s climate system as seen in El Niño-Southern Oscillation (ENSO) events. ENSO events affect sea surface temperatures, resulting in regional temperature and precipitation anomalies that can support epidemics of Rift Valley fever, plague, dengue, cholera, and other pathogens.⁷⁶ With climate change, ENSO events are expected to intensify and increase in frequency.⁷⁷ While localized impacts vary, vulnerability and impacts may be intensified in regions already facing conditions induced by climate change. Forecasting based on information derived from satellite monitoring can identify these conditions months in advance with increasing precision, and help to target where risk may be elevated for specific exposures that can lead to a cascade of impacts relevant for human, animal and environmental health (e.g. drought that increases reliance on unsafe drinking water or forced migration, dry conditions that support wildfires and respiratory disease, flooding and landslides, mosquito proliferation and vector-borne disease, fisheries collapse and food and livelihood security) (Figure 3). While many countries have an early warning system for climate hazards, linking more directly with health systems allows for assessment of a wider scope of expected impacts. A best practice example is the climate and health bulletin published by Colombia’s health and meteorology authorities, with weather forecasts for each of the country’s five regions and an analysis of how climate variability might impact health outcomes (ranging from vector-borne diseases to respiratory diseases).⁷⁸ At present however, forecasting is an under-utilized resource by the health sector to inform adequate risk reduction measures and coping strategies for resilience.

Figure 3. Areas identified with elevated risk of specific diseases linked to ENSO event, 2015-2016. Source: Anyamba et al./Climate.gov



Key Policy Recommendations

Mitigating and adapting to the health impacts linked to climate change requires prudent prioritization by many affected parties. Climate action is not only an international agenda which human health is dependent on; it is also fundamentally linked to action on biodiversity and to reverse land degradation (through the United Nations Convention on Biological Diversity and Convention to Combat Desertification), disaster risk reduction (Sendai Framework), sustainable development (2030 Agenda), and many other multi-lateral agendas associated with environment, cities, trade, agriculture, energy, and economic and social development. Additionally, the interactions between climate and other environmental changes, as well as human behavioral and economic changes, require coordinated action to ensure interventions and policies take an integrated approach to adequately address these interdependencies.

In some of these agendas, such as the SDGs, it is implicit that health will be included as a core area of impact and action – but the scope has historically been narrow, with an emphasis on emergency preparedness and response. Health and climate change must also become a focal point of policy, given its outsized influence and long-term horizon for impact. Some efforts to that end are already underway under the multilateral climate change and biodiversity agendas, as well as in some cross-cutting processes, as described below.

Health in the Climate Change Agenda

The 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change has been deemed by many as the most determinant international climate conference since the adoption of the Paris Agreement, as we come towards the end of the first five-year ambition cycle and countries are expected to submit updated and enhanced NDCs. COP26 is also happening against the backdrop of an ongoing pandemic, and the recent publication of the IPCC WGI report, which provided a stark reminder of the urgent need to both accelerate decarbonization efforts with an unprecedented speed, and prepare to withstand the already unavoidable effects of historic warming.

In this context, the government of the United Kingdom (in its capacity as incoming COP Presidency) has selected health as one of the scientific priorities for COP26, and together with the WHO and Health Care Without Harm (HCWH), has put together the COP26 Health Programme, which is based around the following priority areas:⁷⁹

1. Building climate resilient health systems;
2. Developing low carbon sustainable health systems;
3. Adaptation Research for Health;
4. The inclusion of health priorities in Nationally Determined Contributions;
5. Raising the voice of health professionals as advocates for stronger ambition on climate change

For the first two areas, the COP26 Presidency is calling for countries to publicly adopt national commitments with some minimum criteria. For the initiative on low carbon and sustainable health systems, these include delivering a baseline assessment of the emissions of the national health system and developing a plan to reduce them (and, for high emitting countries, setting a target date by which to achieve net-zero emissions); and for the initiative on resilient health systems, conducting vulnerability and adaptation assessments (V&As) and developing Health National Adaptation Plans (HNAPs), as well as using these tools to access funding from international mechanisms, such as the Global Environment Facility and the Green Climate Fund.

Key policy recommendations stemming from this opportunity include:

Align climate action plans with planning for other priorities at national level. The development and implementation of Health National Adaptation Plans (HNAPs) should be coordinated with those for Nationally Determined Contributions on Climate, National Action Plans on Health Security, National

Action Plans on AMR, and national food security/nutrition strategies. The collective consideration of these topics will ensure climate-sensitive disease risks are adequately considered, that limited resources are optimized across different key objectives, and that prevention, detection, and response capacity is sufficiently strengthened. Doing so will also promote a needed “build back greener” approach to COVID-19 recovery, which could be carbon-intensive if system enhancement financing is not climate-smart.⁸⁰ The health sector itself must be prepared to lead the way on mitigation efforts, by decarbonizing its own facilities and operations, and fostering greater emissions reductions in its supply chain and in all other areas of the broader economy that it is able to influence. HCWH’s *Global Road Map for Health Care Decarbonization* outlines seven high impact actions that the sector can implement to strive for zero emissions by 2050, with a focus on enhancing health equity and resilience.⁶¹ Policy coherence is key if the health sector is to take this vision forward, since it will require close cooperation with many other sectors, including energy, transport, agriculture and industry.

Ensure the health sector is empowered to take a leading role on climate action and health protection. Overall, the health sector is poorly resourced to advance climate mitigation and adaptation efforts – and awareness remains limited, despite the scale of the problem. In the U.S., the accreditation body for schools and programs in public health dropped the requirement for environmental health education in 2016, a decision that may leave the workforce even less prepared to tackle the threat of climate change and effectively work with the many agencies that will be forced to respond.⁸¹ Formally building in academic and applied training on climate change is urgent for public health, human and veterinary medicine, sanitation workers, and emergency response professions. At the global level, increasing overall prominence of climate considerations should be undertaken in health security priorities and financing, including through the forthcoming Global Plan of Action for One Health. Within the WHO, it is crucial to ensure sufficient resourcing for the Health and Environment program to institutionalize partnerships with WMO and downscale early warning systems to county levels, as well as mainstream climate across programs (vector-borne disease, health emergencies, WASH, etc.). Professional health associations and individual health care practitioners can drive meaningful collaboration with other professional associations (e.g. legal, engineering, veterinary, actuarial) to advocate for policies that address climate change and improve human health and socio-economic outcomes.

Invest in climate-smart human, animal, and environmental health systems. This includes low-carbon, resilient- infrastructure upgrades to healthcare facilities and laboratories, adequate training and staffing of workforce on risk pathways and patient- and population-level mitigation and adaptation strategies, improved access to diagnostics and therapeutics in health emergencies and routine care delivery, and Integrated Disease Surveillance and Reporting and other workflow measures to adequately track disease burden and inform resource allocation needs in real time. Robust models have been developed by the World Health Organization, World Bank, and Health Care Without Harm.^{61,82,83} A Planetary Health Defense Fund has recently been proposed that could be a basis for prevention-based financing.

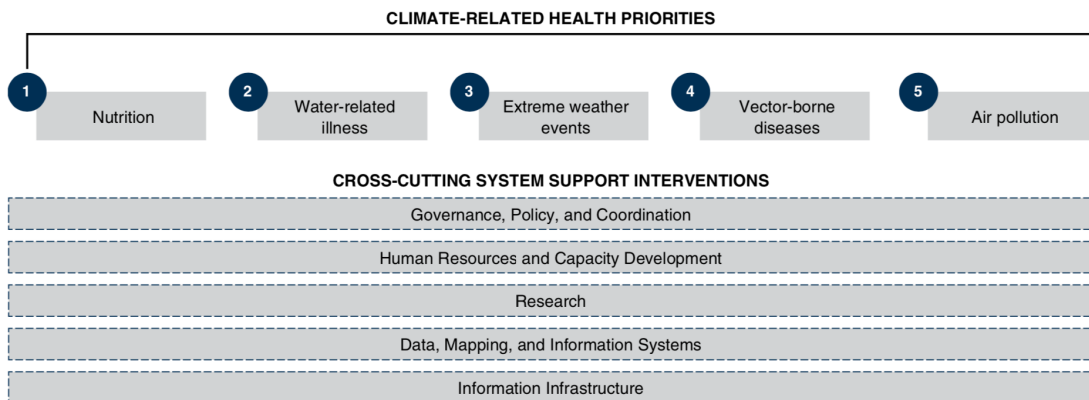
Increase environment sector participation in planning, investment, and implementation of human and animal health systems strengthening initiatives to better assess and manage climate-relevant disease risks. An analysis of Joint External Evaluations (JEE), the WHO tool used to assess country capacity to meet international obligations to prevent, detect and respond to disease threats, indicated that only 20/91 countries included climate- or weather-related terms in their JEE.⁸⁴ This is indicative of a larger issue of limited capacity to assess and manage disease threats linked to environmental degradation, including climate change.⁶⁷ Tools such as the World Bank’s Climate Change & Health Diagnostic (Box 4) can also be used by countries and donors to identify events and conditions where climate stresses and shocks undermine the effectiveness of health systems (at local or national scales), target other shocks and stresses in other sectors that could have negative health consequences, and inform where investment is needed to address weak points.⁸⁵ Building on its recent disaster management guidelines, the World Organisation for Animal Health (OIE) Performance of Veterinary Services (PVS) evaluation missions can also consider capacity needs for prevention and control of climate-sensitive diseases and animal health impacts of extreme weather events.⁸⁶ Climate can also be a lens for International Health

Regulations-Performance of Veterinary Services (IHR-PVS) National Bridging Workshops that bring human and animal health authorities together to improve coordination. Integrating scope into climate and health country profiles on animal and environmental health impacts that can directly and indirectly affect human health can also increase awareness of these links in line with a One Health approach.

Box 4. Climate Change and Health Diagnostic

In 2017, the World Bank developed a methodology for (i) assessing country-level climate and health threats, and (ii) building actionable national responses. This work was built on decades of underlying precedent set by the WHO and other expert assessments of climate-health impact. The World Bank approach, however, connected these assessments to financing channels with the aim of ensuring direct transition into on-the-ground results. Madagascar was the pilot country for this tool, given both its susceptibility to climate-health threats as well as robust existing expertise in climate-health interactions and readiness to deploy new, related programming.⁸⁷ Throughout the diagnostic process, unique climate and health stressors were identified and ultimate points of intervention recommended. These recommendations took into consideration existing threats, expected threats, country capacity, physical/political infrastructure, and financing flows that could impact overall roll-out of programming. The below figure summarizes identified priorities and focus areas for intervention (Figure 4). Each thematic area is further detailed into dozens of considerations and recommendations to enable policy-makers and investors with a blue-print for action.

Figure 4. Priorities and focus areas for intervention covered in the Diagnostic.



Health in the Biodiversity and Environmental Conservation Agendas

Mainstream health into climate change and biodiversity agendas, with adequate funding for implementation. Fragmented mandates across national and international agencies result in incomplete agendas, lack of multi-sectoral ownership, or inability to act on scientific evidence. To complement the important efforts of WHO and other technical agencies on climate and health and create a pathway to directly support Ministries of Environment, there is a need to formalize and resource health programs within the UNFCCC, CBD, and UNCCD, and ensure technical partners are resourced to adequately support implementation of the Rio Conventions and meet targets agreed to in the Paris Agreement and forthcoming Post-2020 Global Biodiversity Framework.** Ensuring coherence between all multilateral environmental agreements (MEAs) and fostering synergies to accelerate their implementation is one of the main objectives of the United Nations Environment Assembly (UNEA), which meets biennially; health should be a priority in the agenda of UNEA VI. Other starting points could include expanded UNEP country office presence, adoption of a capacity assessment tool for environmental health services to

** Convention on Biological Diversity, United Nations Convention to Combat Desertification, and United Nations Framework Convention on Climate Change

complement tools used to assess investment needs for human and animal health systems, and designation of a financing mechanism (such as the Global Environment Facility) to fill relevant environmental health capacity gaps. These actions also align with implementation of the forthcoming UNEP One Health framework, including the involvement of environment sector in One Health projects, training, and capacity strengthening at national level. Identification of management gaps in government ministries relevant to addressing health impacts of climate change should be combined with facilitating relationships between in-country academic institutions and government ministries, using the former to help train and expand the human resources needed to implement relevant policies to address climate change.

Increase scope of impact assessments and institute relevant safeguards. Currently, development projects fail to comprehensively integrate human, animal, and environmental health impact assessment, and health is considered separately from environmental impacts.⁸⁸ Climate change safeguards typically emphasize limiting emissions but poorly address wider climate-linked threats. Integrating environment and health impact assessment into routine practice (with a legal requirement as relevant), requiring ongoing or pre- and post- project monitoring, and implementing safeguard policies to reduce risk, including potentially redirecting the scope or geography of development projects, are first steps to better understand and manage threats more proactively. Globally, a range of additional partners can support action, including multi-lateral and private financing institutions, insurers, other industries (e.g. extractives), the United Nations Industrial Development Organization (UNIDO), and United Nations Human Settlements Programme (UN-Habitat). A specific climate lens should be included, both for acute effects and to factor in longer-term health implications. Positive health benefits that may be achieved, including through programs such as REDD+, should also be accounted for in land use decisions.

Box 5. In Indonesia, a newly established government agency, the Peatland Restoration Agency, aims to restore at least 2 million hectares of damaged peatlands by 2025, a mission that would significantly reduce the fuel potential for escaped fires. Utilizing models built with land cover, winds, precipitation, and other meteorological data can allow the government to strategically decide which peatlands to restore that will have the greatest societal impact. A successful implementation of all the goals set out by this program could result in averting up to 66% of annual excess mortality, saving over 24,000 lives every year.⁸⁹

Increase uptake of nature-based solutions to help avoid future health threats and reduce risk of current disease drivers. Protecting ecosystem services that underpin health and wellbeing is a key focus of the draft post-2020 Global Biodiversity Framework, but successful delivery of targets will require greater integration of climate change and health programs of work under the Convention on Biological Diversity. The health value of nature-based solutions, such as ecosystem-based adaptation benefits already provided by coral reef systems and mangroves in reducing severity of coastal flooding events, is poorly mainstreamed in national financing decisions. Aligning health protection outcomes with the call to action to prevent, halt, and reverse ecosystem degradation under the UN Decade on Restoration (2021-2030) offers an opportunity for immediate progress (see Box 5). A specific effort is needed to protect critical ecosystems identified by the IUCN's Red List of Ecosystems. Doing so will produce multiple co-benefits for nations.

Health in Other Cross-Cutting Processes

At national and global levels, utilize multi-sectoral coordination mechanisms for climate change and health planning and prioritization. To date, single-sector strategies remain the norm in developed and developing nations alike and at the global level; and even within sectors such as health, climate action is often in the margins, rather than mainstreamed across activities. While several working groups and interagency partnership agreements are promising (e.g. the WHO-WMO program, a WHO-IUCN expert working group, and the FAO-OIE-UNEP-WHO 'Tripartite-Plus' Alliance), they require adequate and sustained resourcing and clear articulation of specific target outcomes for accountability. Bringing together major priorities under a multi-sectoral umbrella for routine coordination is crucial to reduce

duplication of efforts, identify unattended gaps, and address potential trade-offs and optimize co-benefits in line with the Sustainable Development Goals. This approach will break down the ‘silos’ in government agencies and donor funding that impede full understanding of drivers and impacts and relevant cost-effective strategies and sectors for capacity strengthening, mitigation, and adaptation – including for health risks and impacts of climate change. Encouragingly, a recent review of 19 National Adaptation Plans (NAPs) found that health was integrated, though to varying degrees – and the impact will only be seen once actually funded and translated to implementation.⁹⁰ The establishment of One Health Coordination Platforms by several countries, often with the support of Heads of State/Prime Ministers, provides a pathway for integrating climate change and health initiatives with a wider array of sectors (e.g. agriculture, education, finance) for greater alignment of priorities and implementation. A forthcoming Global Plan of Action Plan for One Health will reinforce country efforts by identifying coordination priorities for the Tripartite Plus Alliance and should comprehensively include climate change considerations.

Promote equitable access to medical countermeasures and the wider technologies needed to prevent, prepare, and respond to climate-sensitive diseases and wider human, animal, and environmental emergencies. These range from diagnostics, therapeutics, vaccines, resilient seed varieties, safe pesticides, clean energy sources and water and air filtration systems, among others. Emergency situations may require seeking waivers for IP protection. The World Trade Organization should proactively consider how to best support fair and equitable emergency access while also enhancing local and regional climate resilience. Ideally, every geographical region would have its own development/manufacturing capacity to generate relevant technology needs as well as internal markets to sustain and quality assure products.

Commit to firm targets and accountability. Voluntary targets have been long established and revised to address climate change, yet most nations have failed to implement known policies that will reduce atmospheric CO₂. It is evident that voluntary targets are ineffective to meet the threat of climate change; they will need to be obligatory and combined with an independent monitoring system and a series of incentives and penalties for countries that fail to achieve agreed carbon emission targets. Convincing governments to adopt such targets and implement policies to address this existential crisis will require concerted advocacy from a broad swath of society; the voice of the health community can help to bridge the policy implementation gap. Addressing the climate change challenge will also help to address another neglected existential challenge: the global loss of biodiversity. This need also extends to enhanced regulation and enforcement of waste management systems, and overall waste reduction/recycling. Policies exist that can simultaneously address these challenges will result in positive health and social economic outcomes for individuals and nations. Engaging the private sector in these efforts is crucial.

Conclusion

Despite clear evidence of the societal and economic cost of inaction, policy responses are failing to support a global and local health protection stance against climate change risks. The ongoing COVID-19 pandemic tragedy shines light on underlying health system weaknesses that also leave us unprepared for the wide range of health impacts from climate change – and will require major infrastructure investments that must be sensitive to the climate crisis. Challenges in effective pandemic prevention and response from fragmented mandates at global and national levels similarly hinder accountability in addressing climate change and in effectively assessing and reducing disease risk and burden. Ambitious leadership from the health sector is not only essential to minimize human suffering, but can also offer a model for other sectors to act, including by leading the way on aggressive decarbonization. At the same time, building up climate action in other sectors across the SDGs, particularly toward environment-related targets, offers cost-effective opportunities to shift the narrative from responding to impacts to investing in prevention. The world should not miss this critical window to preserve and strengthen our existing prevention potential.

The overview and recommendations presented in this paper offer practical steps in line with a multi-sectoral, One Health approach to link health security and climate action, avoid siloed COVID-19 recovery investments, and enable sustainable, resilient and prepared human, animal, and environmental health systems. They are meant to supplement existing health sector calls to action, reinforcing them while building bridges to additional priorities. COP26 leaders – countries, donors, international agencies, the private sector, research institutions, cities and communities, and individuals - should be bold and unwavering in their commitments, prioritizing health to adequately reduce risk and increase resilience against the climate crisis.

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References

1. IPCC. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2021.
2. Sorensen C, Murray V, Lemery J, Balbus J. Climate change and women's health: Impacts and policy directions. *PLoS Med* 2018; **15**(7): e1002603.
3. IPCC. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, 2018.
4. Allen T, Murray KA, Zambrana-Torrel C, et al. Global hotspots and correlates of emerging zoonotic diseases. *Nat Commun* 2017; **8**(1): 1124.
5. IPBES. Workshop Report on Biodiversity and Pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services. Bonn, Germany: IPBES Secretariat, 2020.
6. Haines A, Ebi K. The Imperative for Climate Action to Protect Health. *N Engl J Med* 2019; **380**(3): 263-73.
7. Hamilton I, Kennard H, McGushin A, et al. The public health implications of the Paris Agreement: a modelling study. *Lancet Planet Health* 2021; **5**(2): e74-e83.
8. Atwoli L, Baqui AH, Benfield T, et al. Call for emergency action to limit global temperature increases, restore biodiversity, and protect health. *Lancet* 2021; **398**(10304): 939-41.
9. World Health Organization. COP26 Special Report: The Health Argument for Climate Action. Geneva, 2021.
10. Watts N, Adger WN, Agnolucci P, et al. Health and climate change: policy responses to protect public health. *Lancet* 2015; **386**(10006): 1861-914.
11. Watts N, Adger WN, Ayeb-Karlsson S, et al. The Lancet Countdown: tracking progress on health and climate change. *Lancet* 2017; **389**(10074): 1151-64.
12. Watts N, Amann M, Arnell N, et al. The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. *Lancet* 2021; **397**(10269): 129-70.
13. Watts N, Amann M, Arnell N, et al. The 2018 report of the Lancet Countdown on health and climate change: shaping the health of nations for centuries to come. *Lancet* 2018; **392**(10163): 2479-514.
14. Watts N, Amann M, Arnell N, et al. The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. *Lancet* 2019; **394**(10211): 1836-78.
15. World Health Organization and Secretariat of the Convention on Biological Diversity. Connecting Global Priorities: Biodiversity and Human Health. Geneva (Switzerland): WHO, 2015.
16. Machalaba C, Romanelli C, Stoett P, et al. Climate Change and Health: Transcending Silos to Find Solutions. *Ann Glob Health* 2015; **81**(3): 445-58.
17. Smith KR, Woodward A, Campbell-Lendrum D, et al. Human health: impacts, adaptation, and co-benefits. In: Field CB, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White, ed. Part A: Global and Sectoral Aspects Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2014: 709-54.
18. Anyamba A, Small JL, Britch SC, et al. Recent weather extremes and impacts on agricultural production and vector-borne disease outbreak patterns. *PLoS One* 2014; **9**(3): e92538.
19. Bressler RD. The mortality cost of carbon. *Nat Commun* 2021; **12**(1): 4467.
20. World Health Organization. Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. Geneva: World Health Organization; 2014.
21. Ebi KL, Capon A, Berry P, et al. Hot weather and heat extremes: health risks. *Lancet* 2021; **398**(10301): 698-708.
22. UNEP. Locust swarms and climate change: Interview with Richard Munang, United Nations Environment Programme expert on climate and Africa. 06 February 2020. <https://www.unep.org/news-and-stories/story/locust-swarms-and-climate-change>.
23. FAO. The State of World Fisheries and Aquaculture 2020. Sustainability in action. . Rome, 2020.
24. Hallegatte SB, Mook; Bonzanigo, Laura; Fay, Marianne; Kane, Tamaro; Narloch, Ulf; Rozenberg, Julie; Treguer, David; Vogt-Schilb, Adrien. Shock Waves : Managing the Impacts of Climate Change on Poverty. Washington, D.C.: World Bank, 2016.
25. World Organisation for Animal Health. Theileriosis: Aetiology, Epidemiology, Diagnosis, Prevention, and Control References, 2021.
26. Waite JL, Suh E, Lynch PA, Thomas MB. Exploring the lower thermal limits for development of the

- human malaria parasite, *Plasmodium falciparum*. *Biol Lett* 2019; **15**(6): 20190275.
27. Waithaka J, Nigel Dudley N, Álvarez M, et al. Impacts of COVID-19 on Protected and Conserved Areas: A Global Overview and Regional Perspectives. *PARKS* 2021; **27**(Special Issue).
 28. The Economist. The pandemic is a gift to poachers in Africa. March 31, 2021.
 29. INTERPOL and ENACT. Illegal gold mining in Central Africa: INTERPOL, 2021.
 30. World Meteorological Society. State of the Global Climate 2020. Geneva, 2021.
 31. Vohra K, Vodonos A, Schwartz J, Marais EA, Sulprizio MP, Mickley LJ. Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem. *Environ Res* 2021; **195**: 110754.
 32. World Health Organization. Health and Climate Change Country Profiles. 2021. <https://www.who.int/activities/monitoring-health-impacts-of-climate-change-and-national-progress>.
 33. Hiatt RA, Beyeler N. Cancer and climate change. *Lancet Oncol* 2020; **21**(11): e519-e27.
 34. Ebi KL. Adaptation costs for climate change-related cases of diarrhoeal disease, malnutrition, and malaria in 2030. *Global Health* 2008; **4**: 9.
 35. Knowlton K, Rotkin-Ellman M, Geballe L, Max W, Solomon GM. Six climate change-related events in the United States accounted for about \$14 billion in lost lives and health costs. *Health Aff (Millwood)* 2011; **30**(11): 2167-76.
 36. Kjellstrom T, Kovats RS, Lloyd SJ, Holt T, Tol RS. The direct impact of climate change on regional labor productivity. *Arch Environ Occup Health* 2009; **64**(4): 217-27.
 37. World Bank. World Development Report 2010: Development and Climate Change. Washington, D.C.: World Bank, 2009.
 38. OECD. The Cost of Air Pollution; 2014.
 39. World Bank, Institute for Health Metrics and Evaluation. The Cost of Air Pollution : Strengthening the Economic Case for Action. Washington, D.C.: World Bank, 2016.
 40. Branca F, Lartey A, Oenema S, et al. Transforming the food system to fight non-communicable diseases. *BMJ* 2019; **364**: l296.
 41. West JJ, Smith SJ, Silva RA, et al. Co-benefits of mitigating global greenhouse gas emissions for future air quality and human health. *Nature Climate Change* 2013; **3**(10): 885-9.
 42. World Bank. State and Trends of Carbon Pricing 2020. Washington, D.C.: World Bank, 2020.
 43. Dobson AP, Pimm SL, Hannah L, et al. Ecology and economics for pandemic prevention. *Science* 2020; **369**(6502): 379-81.
 44. Gopinath G. Reopening from the Great Lockdown: Uneven and Uncertain Recovery. IMF Blog: IMF Blog; June 24, 2020.
 45. FAO. The State of World Fisheries and Aquaculture 2014. Rome: FAO, 2014.
 46. McKenna M. Antibiotics set to flood Florida's troubled orange orchards. *Nature* 19 March 2019; **567**: 302-3.
 47. UNEP. Frontiers 2016 Emerging Issues of Environmental Concern. Nairobi: United Nations Environment Programme, 2016.
 48. Tartari E, Tomczyk S, Pires D, et al. Implementation of the infection prevention and control core components at the national level: a global situational analysis. *J Hosp Infect* 2021; **108**: 94-103.
 49. World Health Organization. Key facts and figures, World Hand Hygiene Day 2021. 2021. <https://www.who.int/campaigns/world-hand-hygiene-day/2021/key-facts-and-figures>.
 50. Fazzo L, Minichilli F, Santoro M, et al. Hazardous waste and health impact: a systematic review of the scientific literature. *Environ Health* 2017; **16**(1): 107.
 51. Health Care Without Harm and Arup. Health care's climate footprint: how the health sector contributes to the global climate crisis and opportunities for action, 2019.
 52. The Brooke Hospital for Animals. One Health at Brooke Case Study - Our Work in Brick Kilns. 2021. <https://www.thebrooke.org/our-work/one-health-brick-kilns>.
 53. Government of the Federal Republic of Nigeria. Nigeria's National Action Plan to reduce Short-Lived Climate Pollutants (SLCPs). Nigeria, 2018.
 54. Gera V. Polish govt, unions initial plan to phase out coal by 2049: The Associated Press, April 28, 2021.
 55. Vasev N. Governing energy while neglecting health - The case of Poland. *Health Policy* 2017; **121**(11): 1147-53.
 56. World Bank. Air Quality Management in Poland. Washington, D.C.: World Bank, 2019.
 57. U.S. Department of Health and Human Services. HHS Establishes Office of Climate Change and Health Equity. August 30, 2021. <https://www.hhs.gov/about/news/2021/08/30/hhs-establishes-office-climate-change-and-health-equity.html>.
 58. World Health Organization. WHO Coronavirus (COVID-19) Dashboard. 2021. <https://covid19.who.int> (accessed October 10, 2021).

59. Institute for Health Metrics and Evaluation (IHME). COVID-19 has caused 6.9 million deaths globally, more than double what official reports show, May 6, 2021.
60. World Health Organization. Preventing Disease Through Healthy Environments: A Global Assessment of the Burden of Disease from Environmental Risks. Geneva: WHO, 2016.
61. Health Care Without Harm and Arup. Global Road Map for Health Care Decarbonization, 2021.
62. Scovronick N, Budolfson M, Dennig F, et al. The impact of human health co-benefits on evaluations of global climate policy. *Nat Commun* 2019; **10**(1): 2095.
63. American Veterinary Medical Association. One Health - A New Professional Imperative, 2008.
64. Whitmee S, Haines A, Beyrer C, et al. Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation-Lancet Commission on planetary health. *Lancet* 2015; **386**(10007): 1973-2028.
65. Steffen W, Richardson K, Rockstrom J, et al. Sustainability. Planetary boundaries: guiding human development on a changing planet. *Science* 2015; **347**(6223): 1259855.
66. Andersen I. Speech prepared for delivery at the Opening Ceremony of the G20 Health Ministers' Meeting. 2021.
<https://www.unep.org/news-and-stories/speech/triple-planetary-crisis-and-public-health>.
67. Berthe FCJ, Bouley TA, Karesh WB, et al. Operational framework for strengthening human, animal and environmental public health systems at their interface. Washington, D.C.: World Bank Group, 2018.
68. Di Marco M, Baker ML, Daszak P, et al. Opinion: Sustainable development must account for pandemic risk. *Proc Natl Acad Sci U S A* 2020; **117**(8): 3888-92.
69. Nilsson M, Griggs D, Visbeck M. Map the interactions between Sustainable Development Goals. *Nature* 2016; **534**: 320-2.
70. World Bank. World Bank Group Approach and Action Plan for Climate Change and Health. Washington, D.C.: World Bank, 2017.
71. Gioutsos A, Ochs A, Majano AM, et al. Crunching Numbers: Quantifying the Sustainable Development Co-Benefits of Mexico's Climate Commitments: Government of Mexico, SD Strategies and the GIZ, 2019.
72. Campbell-Lendrum D, Bertollini R, Neira M, Ebi K, McMichael A. Health and climate change: a roadmap for applied research. *Lancet* 2009; **373**(9676): 1663-5.
73. Ebi KL, Harris F, Sioen GB, et al. Transdisciplinary Research Priorities for Human and Planetary Health in the Context of the 2030 Agenda for Sustainable Development. *Int J Environ Res Public Health* 2020; **17**(23).
74. World Health Organization. Sixty-First World Health Assembly Agenda: Climate change and health. Geneva: WHO; 19-24 May 2008.
75. Jay O, Capon A, Berry P, et al. Reducing the health effects of hot weather and heat extremes: from personal cooling strategies to green cities. *Lancet* 2021; **398**(10301): 709-24.
76. Anyamba A, Chretien JP, Britch SC, et al. Global Disease Outbreaks Associated with the 2015-2016 El Niño Event. *Sci Rep* 2019; **9**(1): 1930.
77. Cai W, Borlace S, Lengaigne M, et al. Increasing frequency of extreme El Niño events due to greenhouse warming. *Nature Climate Change* 2014; **4**(2): 111-6.
78. IDEAM - Instituto de Hidrología MyEA. Climate and Health Bulletin / Boletín Clima y Salud. 2021.
http://sgi.ideam.gov.co/web/tiempo-y-clima/boletin-clima-y-salud/-/document_library_display/y10q4bdJ771V/view/113539450.
79. WHO, COP26 Presidency, HCWH. COP26 Health Programme: Country commitments to build climate resilient and sustainable health systems, 2021.
80. World Health Organization. WHO Manifesto for a Health Recovery from COVID-19: Prescriptions and Actionables for a Healthy and Green Recovery. Geneva: WHO, 2020.
81. Dettman L. The state of environmental health in education. *The Nation's Health*. July 22, 2019.
82. World Health Organization. WHO guidance for climate-resilient and environmentally sustainable health care facilities. Geneva, 2020.
83. World Bank. Climate-Smart Healthcare : Low-Carbon and Resilience Strategies for the Health Sector. Washington, D.C.: World Bank, 2017.
84. Machalaba C, Uhart M, Ryser-Degiorgis MP, Karesh WB. Gaps in health security related to wildlife and environment affecting pandemic prevention and preparedness, 2007-2020. *Bull World Health Organ* 2021; **99**(5): 342-50B.
85. Bouley TA, Ebi K, Golden C, Shumake-Guillemot J, Midgley A. Climate Change and Health Diagnostic: A Country-Based Approach for Assessing Risks and Investing in Climate-Smart Health Systems. Washington, D.C.: World Bank, Climate Group, 2018.
86. Wannous C. Climate change and other risk drivers of animal health and zoonotic disease

- emergencies: the need for a multidisciplinary and multisectoral approach to disaster risk management. *Rev Sci Tech* 2020; **39**(2): 461-70.
87. Bouley TA, Midgley A, Golden C, Ebi K, Shumake-Guillemot J. Madagascar Climate Change and Health Diagnostic: An assessment of Risks and Opportunities for Climate-Smart Health (and Nutrition) Investment. Washington, D.C.: World Bank, Climate Group, 2018.
88. Seifman R, Kornblet S, Standley C, Sorrell E, Fischer J, Katz R. Think big, World Bank: time for a public health safeguard. *Lancet Glob Health* 2015; **3**(4): e186-7.
89. Marlier ME, Liu T, Yu K, et al. Fires, Smoke Exposure, and Public Health: An Integrative Framework to Maximize Health Benefits From Peatland Restoration. *Geohealth* 2019; **3**(7): 178-89.
90. World Health Organization. Health in national adaptation plans: review. Geneva, 2021.