

Impact of Global Environmental Change on Food/Nutrition and Water in Relation to Human Health

Building integrated research and translation to understand and address the challenges with an emphasis on low-to-middle-income countries

21–23 March 2012
Wellcome Trust, London

IMPACT OF GLOBAL ENVIRONMENTAL CHANGE ON FOOD/NUTRITION AND WATER IN RELATION TO HUMAN HEALTH

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CONTENTS

1. Foreword from the Advisory Group
2. Executive summary and recommendations
3. Background
4. Challenges for human health: food and nutrition
5. Challenges for human health: water
6. Challenges for human health: other issues
7. Maximising the power of data at the intersection of health and the environment
8. Creating the right environment for interdisciplinary research
9. Glossary

Annex A Agenda

Annex B Advisory group and Wellcome Trust staff

1. FOREWORD FROM THE ADVISORY GROUP

Humans are having a vast impact on the world in which we live and global environmental change poses a threat to human health like no other we have seen. It is vital that we find more sustainable ways to live, to ensure that the planet can support future generations and to allow them to lead healthy lives. This meeting was timely as we enter discussions on sustainability at Rio+20, where health has not featured as a prominent issue. A new set of development goals will also be created shortly and it is essential that the research community steps up to play its part in addressing these challenges.

A step change is needed as we move away from diagnosis of the problems and towards developing solutions that protect human health through mitigation of and adaptation to global environmental change. Research has a vital role to play in developing these solutions and assessing how effective they are in practice. This will need researchers from different disciplines to work closely together and engage the most vulnerable populations in their work.

The depth of engagement and excitement at this workshop leaves us in no doubt that the research community has the commitment needed to develop these solutions. Now strong leadership is essential to ensure that we all work together to get there.

Dr John Balbus, National Institute of Environmental Health Sciences

Dr Andrée Carter, UK Collaborative on Development Sciences

Prof Anthony Costello, University College London

Prof Anne Johnson, University College London

Prof Judith Wasserheit, University of Washington

2. EXECUTIVE SUMMARY AND RECOMMENDATIONS

In March 2012, the Wellcome Trust convened an international workshop with University College London and the University of Washington to discuss the research community's responses to the major challenges posed by global environmental change to human health and wellbeing. Global environmental change threatens human health on an unprecedented scale, both through direct effects such as extreme weather events and indirectly, through scarcity of safe water and nutritious food. The threats to the health of humans and the planet's ecosystems are exacerbated by demographic changes, including population growth, and increasing consumption.

Around two billion of the world's population currently suffer from undernutrition, and environmental changes will put further pressure on **food** systems. The challenge in the coming decades is to use research to inform the design of food and health systems that are resilient in the face of substantial irreversible environmental changes, such as severe and persistent drought, and environmental shocks, such as flooding. Urbanisation and increasing wealth are leading to dietary and behavioural shifts associated with a rise in obesity that must also be tackled. Both under- and overnutrition will require a combination of technological and policy solutions that will need to be underpinned by research.

Water lies at the intersection between health, food and agriculture, energy, and climate and weather. It is predicted that some of the major health impacts of environmental change will be mediated through water, with an increase in droughts or flooding in some regions. The availability of clean water for hygiene and sanitation is already a significant challenge, and is likely to be exacerbated by the changing climate and rapid urbanisation. Many technological solutions already exist for improving hygiene and sanitation, but there are significant challenges to implementation. Evaluation of interventions and a better understanding of behaviour in this area may contribute to overcoming these difficulties. Understanding the value of water within ecosystems and collecting

further information on the interlinked challenges of water poverty and health were seen as key gaps that could be addressed through research.

Rich data resources have been created in the environmental and health fields that can support research and policy. However, these resources are poorly integrated across fields and geographical scales. Barriers, including technical difficulties, need to be overcome to improve this integration and data must be made both available and accessible through appropriate data-sharing policies. Capacity-building is needed to ensure that the skills are available to extract the most value from existing investments. The workshop also highlighted gaps in the evidence base where further data collection would be desirable, particularly at a local and regional level in low- and middle-income countries.

Attendees discussed the importance of measuring the impact of interventions designed to address problems such as sanitation, undernutrition and overnutrition, and the challenges associated with these evaluations. It was noted that randomised controlled trials may not always be feasible for assessing complex and large-scale interventions. Community engagement, population-level education, awareness and interventions were recognised as having important roles to play.

In order to address the threat of global environmental change to human health, research must:

- build the evidence to develop sustainable, resilient food/nutrition and water systems to provide for 9–10 billion people with limited ecosystem services
- address today's problems as well as tomorrow's
- combine adaptation to environmental change with mitigation
- address issues of quality, quantity, safety and waste.

In order to achieve this research and develop solutions for those in the greatest need, the research and policy community must adopt a bold approach in their research, encompassing the following features:

A. Establish true interdisciplinary research partnerships bringing together a powerful range of disciplines, including environmental, health and social scientists.

- Researchers should establish research collaborations across a wide range of disciplines to address the pressing and tractable data and knowledge gaps.
- Research funders should provide leadership and long-term commitment by:
 - developing appropriate funding mechanisms to support interdisciplinary teams of researchers
 - building capacity through education and training across the global environmental change and health fields in high-, middle- and low-income countries
 - capitalising on existing investments such as cohorts and existing datasets.

B. Consider systems as a whole to ensure that research takes into account the complexities of human and ecosystem interactions.

C. Maximise the value of data, through open access integrated systems with common data-sharing policies.

- Researchers should harness data and emerging technologies to address the research challenges.
- Research funders should maximise the value of existing environmental and health data for research through advocacy work to promote availability and accessibility.

D. Use the most appropriate methodologies to assess causality and evaluate interventions.

- Researchers and funders should develop and build consensus on: the most appropriate methodologies to produce reliable information on causality; and the evaluation of interventions to generate useful evidence for policy making at national, regional and local levels.

E. Focus on the most vulnerable populations and engage communities and research users to ensure that findings are relevant.

- Researchers, policy makers and community stakeholders should work together to: identify key areas for research, including potential approaches, technologies and policy instruments; ensure that research findings are relevant and can be used in practice; and embed research and evaluation in new programmes and activities.

3. BACKGROUND

The changing global environment presents a significant threat to the health and wellbeing of humans and ecosystems. The changing environment includes climate change, ocean acidification, biodiversity loss and deforestation; these challenges cannot be separated from demographic changes – such as growing and ageing populations and migration to urban areas – and increasing consumption. The extent of interaction between humans and the Earth's ecosystems has prompted some to describe the current geological era as the anthropocene or the 'the age of humans', as they consider humans to be not just an inextricable piece of the planetary system, but driving it. Environmental scientists are seeking to quantify tipping points that, once crossed, create a risk of irreversible and abrupt environmental change.

The Wellcome Trust, in partnership with key opinion leaders at UCL and the University of Washington, held an international workshop in response to the major challenges posed by global environmental change to human survival, health and wellbeing. The workshop considered the growing demand from researchers, governments and communities for data about how the impact of these changes will be mediated by changes in the availability and quality of food and water, and the need for research and translation to create resilient food and water systems to protect and promote human health.

This workshop brought together academics from a wide range of disciplines, practitioners, funders, policy makers, governmental organisations and industry to discuss the research needed to address the challenges to human health posed by food/nutrition and water insecurity as a result of environmental change. The agenda is included at Annex A. One session of the workshop focused on the importance of integrated data systems for developing solutions to these challenges and this also emerged as a key cross-cutting theme throughout the workshop.

The aims of the workshop were to:

- **identify key interdisciplinary research challenges and translation opportunities** relevant to the impact of environmental change on health, nutrition and water
- **catalyse development of a critical mass of leaders from the health and environmental change fields** who can influence and facilitate new avenues of exploration
- **initiate and foster new interdisciplinary collaborations**, particularly between researchers in health and environmental change fields and those working in low- and middle-income countries
- **develop and initiate strategies to build capacity for interdisciplinary research** that is relevant to those most affected by the challenges.

This report discusses potential significant research and translation gaps in the areas of water and food and key cross-cutting barriers that must be overcome in conducting and using this research.

4. CHALLENGES FOR HUMAN HEALTH: FOOD AND NUTRITION

Presentations

Professor Lisa Graumlich, Dean of the College of Environment at the University of Washington, called for a bold, interdisciplinary approach to research on the challenges posed by global environmental change in order to build resilient systems to protect and promote health.

Professor Andrew Challinor, Professor of Climate Impacts at the University of Leeds, presented the merits and limitations of climate and crop models, emphasising the importance of developing models on appropriate spatial and time scales, as well as challenging models with observations.

Dr David Nabarro, Special Representative of the UN Secretary General for Food Security and Nutrition, called for a holistic view of mitigating environmental change impacts on human health at a policy level: integrating economy, environment and society, rather than the more traditional siloed approach.

Discussion

It is counterintuitive that in a world of plenty, one billion go hungry and a further billion suffer from ‘hidden hunger’: they are deficient in key nutrients despite consuming sufficient calories. The food price spikes of 2007–08 and 2010 led to stark recognition that there are major problems in the world’s agricultural and food system. There is increasing acknowledgement that different sectors – including agriculture, environment, economics and health – will need to work together to address food insecurity. Nutrition is now seen as an important part of the challenge of food security, prompting some to suggest that ‘nutritional security’ may be a more appropriate goal.

Environmental change will put further pressure on food systems, for example through predicted changes in rainfall and temperature. Beyond climate change, other environmental changes will impact on food systems and nutrition: for example, ocean acidification and over-fishing are affecting aquatic ecosystems and local food availability. The challenge in the coming decades is to design and manage food and health systems that are resilient in the face of short-term environmental shocks and large-scale, irreversible environmental changes, such as severe and persistent drought and regional shifts in climate. Climate and crop models are important for predicting the challenges that health and food systems will face and for informing the development of appropriate responses.

Case studies – health impacts of environmental change and food

Climate change and nutrition

Climate change is predicted to increase levels of undernutrition, with particularly severe effects in sub-Saharan Africa. The impact of climate change is expected to reduce the daily per capita calorie availability to below 2000 in sub-Saharan Africa by 2050, leading to an increase in undernourished children in the region from 33 million in 2000 to 52 million in 2050. The International Food Policy Research Institute estimates that \$7 billion investment per annum would be required to increase agricultural productivity sufficiently to offset the negative impacts of climate change.

Vegetation and child health

Molly Brown, NASA, reported there was a significant negative relationship between the health of vegetation during the year of birth and mortality, wasting and stunting of children under five years of age in a range of areas including Mali (2001 and 2006), Burkina Faso (2003) and Malawi (2010).

Smallholder farmers who rely on their crops and livestock for both food and income are most vulnerable to the impact of environmental changes. It is expected that increases in temperatures will be correlated with a decline in the ability to undertake manual labour, which will compound the impact of climate change on yields. Across the world there are half a billion smallholder farmers, predominantly women, and a further two billion depend on these farms for their health and livelihood. Research has also shown that nutrition in the first 1000 days of a child's life is key to their future health. These vulnerable groups should be put at the centre of research and translation attempts to address nutrition and food insecurity, to ensure that they are protected as far as possible from the impacts of environmental change.

In addition to undernutrition, workshop participants saw obesity as a key health issue to address. Increasing wealth and migration from rural to urban settings are creating a shift away from traditional lifestyles and diets towards more sedentary lifestyles and the unhealthy 'Western diet', high in refined foods, sugars and saturated fat. This 'nutrition transition' poses a major threat to health and means that low- and middle-income countries are exposed simultaneously to high levels of undernutrition and overnutrition.

Agriculture contributes around 10–12 per cent of global greenhouse gas emissions. 80 per cent of these emissions are derived from livestock production. High intake of food from animal sources, which contains high levels of saturated fat, is associated with negative health outcomes, including cardiovascular disease. This highlights the importance of making progress towards defining locally acceptable sustainable diets that are nutritious, affordable and low in environmental impact.

Research and translation opportunities in the context of food and nutrition

Global environmental change will have a profound impact on agriculture: for example, increases in temperature and drought will impact on yields, exacerbating undernutrition. Demographic changes are also having a strong influence on diets. Interventions designed to tackle both undernutrition and overnutrition must take into account the important role of behaviour and be robustly and appropriately evaluated. Opportunities in this area include:

- improving understanding of:
 - nutrient content of locally available foods, in order to improve diets and build resilience
 - the composition of healthy sustainable diets for different populations, now and in the future, that minimise the impact on the environment
 - dietary shifts, food choice and behaviour change
 - links between agriculture, health and water conservation, and thereby the impact of environmental changes
- developing and evaluating interventions to:
 - address micronutrient availability and stunting and nutrition in the first 1000 days
 - bring about behavioural and lifestyle changes, such as an increase in physical exercise
 - make food systems more resilient to environmental change through economics, policy and technology.

5. CHALLENGES FOR HUMAN HEALTH: WATER

Presentations

Dr K Palanisami, Director of the International Water Management Institute in India, argued that to understand and address the health impacts of environmental change mediated by water, we require a better understanding of the ecosystem context and should take an ecosystem approach.

Rifat Hossain from the World Health Organization spoke about water in the context of sanitation and outlined the challenges associated with effects of climate variability and change in access to safe water, which are compounded by a knowledge gap in this area.

Professor Jamie Bartram, Director of the Water Institute at the University of North Carolina, outlined: the significant global burden of disease due to water-related risk factors; the multiple and complex factors driving impacts on health; and the opposing effects in low-income countries of water excess and scarcity.

Discussion

Water was considered the ultimate integrator, lying at the intersection between health, food and agriculture, energy and industry, and climate and weather. Since water is intimately linked to ecosystems it cannot be considered separately from other issues such as ecological degradation.

Many diseases are mediated by water, for example water-borne diseases that are transmitted by drinking contaminated water and water-based diseases where the pathogen host lives in water or requires water for part of its life cycle. Water and poor hygiene and sanitation are associated with a high global disease burden, including two million preventable deaths per year from diarrhoeal diseases. Currently around one billion people lack access to safe, clean water; addressing water poverty is crucial to improve health. Further, 2.6 billion lack access to adequate sanitation, with high levels of disease caused by contact with untreated or uncontained human waste and poor hygiene.

Excess water, such as flooding caused by extreme weather events or man-made changes such as dams, poses risks to health, including infectious disease outbreaks, drowning and the psychological impact of being displaced from home. With climate change, water runoff is expected to increase at high latitudes.

Similarly, water scarcity, caused by droughts or other factors such as urbanisation, can also have a negative impact on health through an impact on crop yields and food supplies and the availability of clean water for drinking and sanitation. Declining water resources such as falling water tables and from the impact of salination of drinking water are already being reported, and runoff is expected to decrease over some subtropical and tropical regions with climate change. Rapid urbanisation, particularly the growth of slums where infrastructure struggles to keep pace with demand, poses particular challenges to the delivery of adequate sanitation.

Water is intrinsic to several of the Millennium Development Goals. While some progress has been made towards achieving these goals, this is not sufficient when the scale of water poverty is considered. Furthermore, the difficulties of providing access to sufficient, safe water are exacerbated by the multiple pressures on the water system, such as climate change, extreme weather events, population growth and competing demands such as from industry. A combination of a lack of comparable data from different geographical areas and time points, fragmented initiatives in the area, and poor understanding of the effects of climate variability and change on access to safe water are considered to have made effective policy formulation difficult.

Case studies – health impacts of environmental change and water

Saltwater intrusion in coastal Bangladesh

High levels of salinity in drinking water for around 20 million people have been caused by river flow changes, sea level rise, irrigation and shrimp farming. Levels of mean urinary sodium in pregnant women of around double the World Health Organization recommended level have been reported, with prevalence of pre-eclampsia highest in dry season.

Consequences of the December 2004 tsunami on the Indian coastal ecosystem

The groundwater quality was affected and land was degraded because of salt water inundation. Crop yield and income were reduced and post-traumatic stress disorder symptoms increased. Hydrological processes took 1.5 years to recover, agriculture took three years and the socio-psychological impact lasted for around five years.

The recent Vision 2030 study examined the projections of climate change and its impact on drinking water and sanitation systems and potential adaptation to address these issues. The report found that although climate change predictions are uncertain at a regional level, knowledge does exist to inform change in policy and planning. However, the report also highlighted important knowledge gaps that must be addressed to enable effective action.

Research and translation opportunities in the context of water

Global environmental change will compound the negative impacts of water on health and demographic changes will put further strain on water systems. Opportunities in this area include:

- improving understanding of:
 - where the most vulnerable communities are – to allow targeting interventions and improve our understanding of the social implications of water poverty on individuals, families and society (development of a water poverty-health index was recommended to help map this vulnerability)
 - reasons for a lack of access to safe water and poor sanitation and how this might be affected by environmental and demographic changes
 - health impacts of urbanisation and of new and ageing water infrastructure in cities
 - physical and mental health impacts of floods and droughts, which will increase with environmental change, on individuals and communities
 - future demand for water and the role of technology and management
 - how we balance the short-term benefits of exploitation of water resources with long-term costs of environment and health degradation
 - whether an economic value of water can be defined to prioritise conflicting demands for water from different sectors, such as food production, energy and domestic use
 - the ethical dimensions of human water use and water poverty
- developing and evaluating interventions on:
 - the many water and sanitation technologies that already exist but need to be implemented in a sustainable way and evaluated to assess their impact on health (incremental changes could include deepening and replacing bore holes; transformational changes could include micro-piped household-level water access and scaling up dry sanitation)
 - different measures of ‘greening’ cities, particularly around water infrastructure and initiatives to improve water management, and their health outcomes and physical impacts).

6. CHALLENGES FOR HUMAN HEALTH: OTHER ISSUES

The availability of nutritious food and clean water are essential for good health. However, not all of the impacts of environmental change are mediated through these routes. For example:

- variations in weather and climate are expected to affect the range and intensity of **infectious diseases outbreaks** – for example, El Niño is correlated with malaria, dengue and cholera outbreaks
- climate change is predicted to increase the frequency of extreme weather events and **natural disasters**, such as heatwaves (the greatest impacts will be seen in low- and middle-income countries: in 2010, 32 million people in China and Pakistan were affected by floods, and in Russia, a 30 per cent decline in the wheat harvest and 56 000 extra deaths were attributed to drought and fires)
- environmental changes and natural disasters will lead to **migration** as populations seek to avoid the worst impacts
- **climate change mitigation strategies** may have positive or negative impacts on health: for example, cleaner electricity generation will reduce air pollution, but growing biofuels may limit space for food production.

7. MAXIMISING THE POWER OF DATA AT THE INTERSECTION OF HEALTH AND THE ENVIRONMENT

Presentations

Chet Koblinsky, Director of Climate Program Office, US National Oceanic and Atmospheric Administration, discussed the range of current climate data and the importance of integrating these with health information and using interdisciplinary teams to interrogate them, to address key societal challenges.

Dr Letitia Obeng, Chair, Global Water Partnership, described the need for compatible and comprehensive data in order to understand the interactions between water, the changing environment and health and to inform decision making.

Dr Molly Brown, Research Scientist, NASA, described the importance of monitoring both local food prices and local agricultural production in semi-arid subsistence agricultural systems to assess food security.

Dr Madeleine Thomson, Senior Research Scientist, International Research Institute for Climate and Society, highlighted the role of the Institute and its partners in overcoming key gaps in policy, practice, services and data that will enable better management of climate-related risks to health in Africa and elsewhere.

Dr Dan Bloomfield, Research Development Manager, University of Exeter and Met Office UK, identified the challenges related to realising the value of meteorological services for research questions on environmental change and its impact on human health.

Dr Taha Kass-Hout, Deputy Director of Information Science and BioSense Program Manager, Centers for Disease Control and Prevention, described the possibilities offered by emerging technologies and tools in the integration of data systems and monitoring of health and disease.

Discussion

There is a **growing demand for information about how global environmental change influences human health and wellbeing**, for example through food and water. Research adds to this information through modelling, measuring and attribution, which can be used to inform policy and decision making, for example:

- monitoring and predicting climate and weather patterns and long-term trends for planning, such as vulnerability assessments to identify populations at risk
- predicting extreme event magnitude and persistence, for example to underpin early warning systems
- combining disease and climate data to improve the control of emerging and re-emerging diseases, such as the timing of interventions, and to provide early warning of potential epidemics.

Participants emphasised the importance of both **observational data and modelling** in generating information on environmental change and health. Longitudinal data that provide long-term information on a specific area or impact were seen as particularly important. Models should be tested with observational data to ensure that predictions are as robust as possible. Multiple model simulations are routinely used to quantify the range of possible future climates across the globe, which has led to an increasing use of the concepts of predictability of weather and climate. Those using models should ensure that they are aware of the limitations and it was noted that this can be a particular challenge for users from other disciplines.

Key challenges and opportunities

Current data systems and tools are often designed around a specific area, such as meteorology or food prices. While there could be significant value in linking information between areas, there are barriers to the **integration of data systems**. Constructing models that adequately capture the coupling of environmental and human systems across temporal and spatial scales remains daunting. There are technical difficulties that need to be overcome to enable better data integration. For example, data systems are not interoperable, partly because of a lack of common protocols and language across areas.

Collection, analysis, storage and maintenance of high-quality data are costly. Participants stressed the importance of ensuring that maximum value can be gained from existing data, including historical information, through digitisation of the ‘back catalogue’, validation and reanalysis. It is essential for reanalysis and the development of tools for decision making that data are made available and accessible through appropriate **data sharing**, which can be facilitated by open access and common data-sharing protocols.

Case studies – data systems

The Global Earth Observation System of Systems (GEOSS)

Inter-governmental organisation with 88 member countries that was established in 2005 to provide Earth observational data for the benefit of society and policy making. GEOSS covers a range of areas including agriculture, climate, health, biodiversity and energy.

www.earthobservations.org/geoss.shtml

The WHO Global Health Observatory (GHO) system

The GHO data repository provides access to over 50 datasets on priority health topics including mortality and burden of diseases, the Millennium Development Goals (child nutrition, child health, maternal and reproductive health, immunisation, HIV/AIDS, tuberculosis, malaria, neglected diseases, water and sanitation), non-communicable diseases and risk factors, epidemic-prone diseases, health systems, and environmental health. GHO includes the Global Information Management System, a comprehensive data management system based on interoperable and open source data.

www.who.int/gho/en/

Policy makers at local and national levels need **relevant information** to allow them to prepare for short-term scenarios, such as floods and droughts. However, in many cases climate and weather information is not readily available or accessible. It is important that data are available across a range of both temporal and spatial scales but there is a significant lack of accurate basic data in most low-income countries in a wide variety of areas. Where data are available, it is important that they are presented in a form that is accessible for users. Development of a common language between those generating and those using evidence may help to ensure that data fit users' needs.

Case study – Information for local needs

The International Research Institute for Climate and Society (IRI) acts as a catalyst for the creation and provision of science to meet the needs of low-income countries. IRI collaborates with partners in Africa, Asia and Latin America, with local institutions that understand local needs and capacity. IRI seeks to produce the best and most relevant climate information for effective climate risk management in sectors such as agriculture, water resource operation, food security and public health. The research and tools are demand-driven in that they help solve specific development, adaptation and research management issues.

portal.iri.columbia.edu/portal/server.pt

The appropriate **capacity** and **tools** are often not available to collect, validate, analyse, interpret and report data at a local level, particularly in low- and middle-income countries; many such countries lack a national meteorological agency, for example. It is important that countries assemble expertise in all sectors to ensure they can use data appropriately and it was considered that the role of information brokers is often overlooked.

Participants discussed the role of **emerging technologies**, which present exciting possibilities in the integration of data systems and metrics for the monitoring and improvement of human health. The internet, global positioning systems, mobile phone data, and social media and crowd-sourcing were seen to provide many powerful tools that can be used in this area. In addition to gathering data, these technologies may have important roles to play in providing solutions to the challenges discussed, such as tele-health or mobile health. New technologies now allow for weather- and climate-based systems to provide early warning of incipient epidemics and could provide considerable population health benefit if informatics, structural and financial barriers to implementation can be overcome.

Case study – Digital disease detection

HealthMap utilises informal online sources for disease outbreak monitoring and real-time surveillance of emerging public health threats. Through an automated process the system monitors, organises, integrates, filters, visualises and disseminates online information about emerging diseases in nine languages, facilitating early detection of global public health threats.

www.healthmap.org/about/

8. CREATING THE RIGHT ENVIRONMENT FOR INTERDISCIPLINARY RESEARCH

In addition to the availability and accessibility of data, the workshop explored the requirements for performing high-quality interdisciplinary work in the area of global environmental change and health. This section discusses these requirements, which were seen to be shared across the fields, and current barriers to progress.

Issue-led collaborations

Participants considered that effective adaptation to global environmental change is still possible, but requires an approach that is focused on issue-led rather than discipline-led collaborations. This will mean bringing together teams across disciplines to introduce the necessary breadth of expertise to tackle these complex and dynamic problems. Currently, different disciplines tend to operate in silos and these divisions can be exacerbated by the systems and structures in place across academic institutions, governments, journals and funders. A common vision is required across the different stakeholders to ensure that divisions are broken down and a holistic approach is taken to these challenges.

The health community has now started to engage with environmental issues, but some noted that this has been a slow process and that more progress is needed. Participants suggested a number of short- and long-term approaches to foster interdisciplinary working, including:

- training researchers in interdisciplinarity
- incentivising researchers and key stakeholders to work with other disciplines
- building capacity in the next generation of researchers through school and university education, particularly in low- and middle-income countries
- focusing teaching around solving problems, rather than around disciplines
- building institutional research capacity in this field.

Participants noted that funders have an important role to play in catalysing this research. It was considered that funders should work multilaterally to develop new models of long-term funding that facilitate interdisciplinary working and reduce the perceived risk of applying for funding to conduct these types of studies.

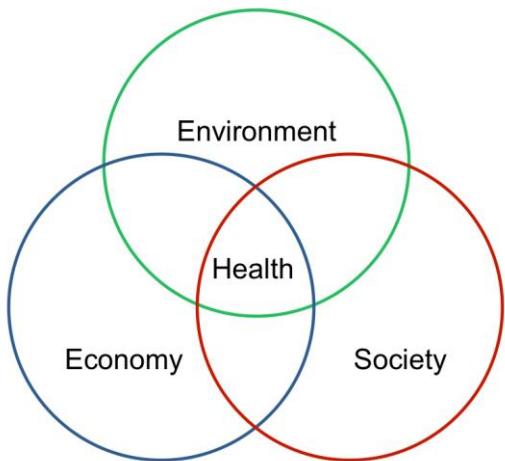
Taking a systems approach

The extent of interdependencies between humans and the environment, discussed earlier in this report, poses challenges for the way we conduct research. Many of the impacts of environmental change on health are mediated via complex systems, such as water and food. A better understanding of the system context is needed to address and manage the impacts of environmental change on health. For example, water and food systems are dependent on the state of the ecosystem, and therefore the restoration and maintenance of ecosystems is needed to foster good health and wellbeing. However, human-driven components of these systems, such as trade, also play important roles. It is therefore essential that all three pillars of sustainability – economy, environment and society – are taken into account in both research and policy, to ensure a robust approach.

Many participants advocated taking a systems approach to research in this area, proposing two potential systems models:

- an **ecosystems approach**, which provides a framework for looking at whole ecosystems and for valuing the ecosystem services they provide (Figure 1)
- the **DPSEEA framework** (Driving Force–Pressure–State–Exposure–Effect–Action), which helps assess the complex relationships among the various driving forces for a problem and identify appropriate interventions.

Figure 1: An ecosystems approach



Community engagement, user-led research and uptake of findings

While research must take into account the system context in which it operates, research is also needed at all levels from global to local. Many of the solutions to the health challenges posed by environmental change will be driven by policy rather than technology; and to be effective, solutions will need to be locally relevant.

A key theme throughout the workshop was that to promote uptake of research findings, research must address the problems faced by the people who will use it. Since there is often a poor understanding of local needs, user-led research is important to engage local populations or decision makers to identify the most pertinent research questions and ensure that research is targeted where there is demand. Many considered that researchers also need to take responsibility for disseminating their findings to those involved and to different groups to whom it is relevant, such as community groups and local or national government.

Population-level behavioural and cultural change will be necessary alongside science, technology or policy interventions to address the challenge of global environmental change. Participants noted that there is limited evidence on the most effective ways to influence behaviour change. However, engaging local populations to ensure that interventions of any type are socially and culturally appropriate was seen as a positive step forward.

Evaluating interventions

It is important that interventions to address the health impacts of environmental change are robustly evaluated to ensure they can be effectively implemented and disseminated. Interventions in this area may involve changes in technology, policy or behaviour. Interventions may also be large-scale and have multiple interrelated goals, such as adaption or mitigation, improving nutrition, and poverty alleviation. These factors can make assessing effectiveness complex. While randomised controlled trials remain the gold standard for evaluating interventions, participants considered it important to recognise that other methodologies may sometimes be more appropriate or useful in certain

settings. This may need the development of understanding about what constitutes robust enough evidence to assess causality and to support wider implementation of an intervention.

The ways in which individuals and the community respond to an intervention is vital for its success and is complicated by the role of human behaviour. Community engagement and communication are therefore vital in designing and evaluating interventions.

9. GLOSSARY

DPSEEA framework

The DPSEEA (Driving Force–Pressure–State–Exposure–Effect–Action) framework adopts a linear approach to mapping environment and health issues, from high-level cultural and political drivers of environmental change to pressures which modify the physical environmental to produce an environment with defined characteristics or state.

Ecosystem

A biological system consisting of all the living organisms in a particular area and the nonliving factors with which the organisms interact, such as air, mineral soil, water and sunlight.

Ecosystem services

The processes by which the environment produces resources utilised by humans such as clean air, water, food and materials. Ecosystem services can be defined in various ways. For example, the Millennium Ecosystem Assessment defines supporting services, provisioning services, regulating services and cultural services.

Malnutrition

People are malnourished if their diet does not provide adequate calories, protein or micronutrients for growth and maintenance or if they are unable to fully utilise the food they eat due to illness (undernutrition). They are also malnourished if they consume too many calories (overnutrition).

Millennium Development Goals

The eight Millennium Development Goals (MDGs) – which range from halving extreme poverty to halting the spread of HIV/AIDS and providing universal primary education, all by the target date of 2015 – form a blueprint agreed to by all the world's countries and all the world's leading development institutions. A new set of development goals will be established to replace the MDGs after 2015.

Nutrition transition

A series of changes in diet, physical activity, health and nutrition that are associated with overnutrition.

Overnutrition

Consumption of too many calories. Includes obesity.

Randomised controlled trial

An experimental approach to studying interventions where the study subjects are randomly allocated between an intervention group and a control group that is not receiving the intervention.

Undernutrition

Lack of adequate calories, protein or micronutrients for growth and maintenance, or where an individual is unable to fully utilise the food they eat due to illness.

Water poverty

Describes a lack of access to clean water or adequate sanitation.

ANNEX A: AGENDA

Wednesday 21 March

17.30	Registration and pre-dinner drinks	6th floor
18.30	Welcome and introductions <i>Professor Anne Johnson, UCL and Wellcome Trust Governor</i>	Rooftops Restaurant, 5th floor
18.45	Keynote presentation <i>Dr Lindiwe Sibanda, FANRPAN</i>	
19.15	Dinner	

Thursday 22 March

08.15	Tea and coffee	6th floor
08.30	Recap of the workshop aims <i>Professor Anne Johnson, UCL and Wellcome Trust Governor</i> <i>Dr Richard Seabrook, Wellcome Trust</i> <i>Professor Judith Wasserheit, University of Washington</i>	

Session 1: Impact of global environmental change on food/nutrition and human health: opportunities and challenges

Co-Chairs: Professor Anthony Costello, UCL and Professor Gebisa Ejeta, Purdue University

08.50	Earth system perspectives on human health and food security <i>Professor Lisa Graumlich, University of Washington</i>
09.05	Food, health and environment: a climate impacts perspective <i>Professor Andrew Challinor, University of Leeds</i>
09.20	A perspective from current Intergovernmental processes <i>Dr David Nabarro, United Nations</i>
09.35	Panel session <i>Dr Harshpal Sachdev, Sitaram Bhartia Institute of Science and Research, will join the speakers and chairs of session 1 to form the panel</i>
10.05	Tea and coffee break
10.20	Breakout session Questions to be addressed by breakout groups: <ul style="list-style-type: none">• What are the priority research gaps/questions to improve our understanding of and address the impact of global environmental change on human health mediated by changes in the availability and/or quality of food?• What are the key barriers to collaboration/joint working across disciplines on these questions, how can these be overcome?• What are the potential translational gains/opportunities and what is needed to achieve them?
11.45	Feedback from breakout groups
12.45	Lunch

Session 2: Impact of global environmental change on water and human health: opportunities and challenges

Co-chairs: Professor John Balbus, NIH, and Dr Letitia Obeng, Global Water Partnership

- 13.45 Ecosystems perspective
Dr K Palanisami, International Water Management Institute
- 14.00 Water systems perspective
Mr Rifat Hossain, WHO
- 14.15 Health sciences perspective
Professor Jamie Bartram, University of North Carolina
- 14.30 Panel session
Dr Salmeel Huq, International Institute for Environment and Development, will join the speakers and chairs of session 2 to form the panel
- 15.00 Tea and coffee
- 15.15 Breakout session
Questions to be addressed by breakout groups;
- What are the priority research gaps/questions to improve our understanding of and address the impact of global environmental change on human health mediated by changes in the availability and/or quality of water?
 - What are the key barriers to collaboration/joint working across disciplines on these questions, how can these be overcome?
 - What are the potential translational gains/opportunities and what is needed to achieve them?
- 16.30 Sustainable development goals
Richard Horton, *Lancet*
- 16.40 Feedback from groups and discussion
- 17.50 Coaches depart for Shakespeare's Globe Theatre (coaches will depart from Gower Place at the back of the Gibbs Building)
- 18.30 Drinks and Dinner at Shakespeare's Globe Theatre
Hosted by Sir William Castell, Chairman, Wellcome Trust
After dinner the coach will take guests back to the Holiday Inn Bloomsbury

Friday 23 March

08.45	Tea and coffee	6th floor
09.00	Welcome back	
Session 3: Integrated data systems and metric for the interlinked challenges of global environmental change and health		
Co-Chairs: Professor Majid Ezzati, Imperial College London, and Professor Jonathan Patz, University of Wisconsin		
09.05	Large-scale integrated data systems related to climate change <i>Chet Koblinsky, NOAA</i>	
09.20	The value of data for sustainable water management <i>Dr Letitia Obeng, Global Water Partnership</i>	
09.35	The impact of weather on agricultural production in poor, semi-arid subsistence agricultural systems and access to food through variations in local staple food prices <i>Dr Molly Brown, NASA</i>	
09.50	Climate data for better health: connecting the dots... <i>Dr Madeleine Thomson, International Research Institute for Climate and Society</i>	
10.05	We need a strong, virtuous circle of data between weather services and the health sector to combat weather-related diseases <i>Dr Dan Bloomfield, Met Office UK</i>	
10.20	Emerging technologies <i>Dr Taha Kass Hout, CDC</i>	
10.35	Panel session <i>The speakers and chairs from session 3 will form the panel</i>	
11.05	Tea and coffee	
11.20	Breakout session Questions to be addressed by breakout groups:	
	<ul style="list-style-type: none">• What are the priority mutual data needs and key challenges to facilitate interdisciplinary research at the nexus of global environmental change, water, food and human health?• What are the key barriers to sharing data, strengthening data standards/protocols and systems, and linking data systems/language/elements for interdisciplinary research in these areas, and how can these be overcome?• What are the potential translational gains/opportunities and what is needed to achieve them?	
12.30	Lunch	
13.30	Feedback from breakout session	

Session 4: Final general discussion and outcomes

Co-Chairs: Professor Anne Johnson, UCL and Wellcome Trust Governor, and Professor Andy Haines, London School of Hygiene and Tropical Medicine

14.30 Synthesis of key points from previous sessions
Professor Andy Haines, LSHTM

15.15 Tea and coffee

15.30 \$5 Million Challenge – group workshop

17.15 Wrap up and close

17.30 Closed advisory Organising Group Meeting

ANNEX B: ADVISORY GROUP AND WELLCOME TRUST STAFF

Advisory Group

Dr Andrée Carter, Director of the UK Collaborative on Development Sciences

Professor Anthony Costello, Professor of International Child Health and Director of the UCL Institute for Global Health, University College London

Dr John Balbus, Senior Advisor for Public Health, National Institute of Environmental Health Sciences

Professor Anne Johnson, Professor of Infectious Disease Epidemiology and Co-Director of the UCL Institute for Global Health, University College London; also a Wellcome Trust Governor

Professor Judith Wasserheit, Vice Chair, Global Health, School of Public Health, University of Washington

Wellcome Trust staff

Shewly Choudhury

Nidhee Jadeja

Michelle Jimenez

Melissa Lewis

Richard Seabrook

Beth Thompson

Jimmy Whitworth

Wellcome Trust

We are a global charitable foundation dedicated to achieving extraordinary improvements in human and animal health.

We support the brightest minds in biomedical research and the medical humanities. Our breadth of support includes public engagement, education and the application of research to improve health.

We are independent of both political and commercial interests.

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