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The case for systems thinking about climate change and mental health

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It is increasingly necessary to quantify the impacts of climate change on populations, and to quantify the effectiveness of mitigation and adaptation strategies. Despite growing interest in the health effects of climate change, the relationship between mental health and climate change has received little attention in research or policy. Here, we outline current thinking about climate change and mental health, and discuss crucial limitations in modern epidemiology for examining this issue. A systems approach, complemented by a new style of research thinking and leadership, can help align the needs of this emerging field with existing and research policy agendas.

There is growing apprehension about the effects of current and future climate change on human health[1–3], with particular concern for some of the world's most vulnerable regions[4–7]. Following from unease about the general health impacts of climate change is an emerging interest in mental health specifically. However, mental health needs[8], funding of services[9] and research[10] are not being adequately addressed. The same neglect is reflected in research investment in the mental health implications of climate change[11]. For instance, a Scopus search yielded 9,672 publications for 2007–2016 matching the terms "climate change AND health", but only 208 were returned for "climate change AND mental health". Only 29 of these critically evaluated mental health, and the rate of publication on this topic domain has remained flat. Mental health, including its relationship to climate change, urgently needs greater priority. Here, we outline current thinking on this topic, describe relationships to modern epidemiology and propose the adoption of a systems approach to remedy present limitations. We finish by introducing a top-level causal process diagram, some notes about research methods and approaches that could be applied, a future research agenda and a comment on the style of scientific leadership that will be required.

Current thinking

Publications directly addressing climate change and mental health mainly comprise commentaries and reviews with limited empirical investigations (primarily set in local, usually rural, communities). A common observation is that climate change is unlikely to generate new classifications of psychiatric disorder, instead aggravating well-known risk factors for already-existing disorders[12]. For example, climate-change-related increases in extreme events mean that more people will be exposed to circumstances known to exacerbate existing mental disorders[9,13] or to provoke first onset (see Box 1 for the adverse mental health impacts of flooding).

Hot days and heatwaves are particularly concerning because of their prevalence and danger, and the statistical effect size of hot days on population mental health approximates that of unemployment[14]. Night-time heat, projected to increase with climate change, is associated with poorer sleep[15], a cause and consequence of poor mental health[16], and some psychoactive medicines become ineffective during heatwaves[17]. Just as heat best predicts mortality in conditions of high humidity[18], so hot days are particularly strongly associated with deterioration in population mental health and well-being in humid weather[19,20] (these associations vary seasonally[21]). Heatwaves aggravate various mental disorders[22], especially (though not exclusively[23])

affecting people in lower-income and middle-income countries[24]. Heatwaves in Adelaide, South Australia, for example, caused excess hospital admissions for psychiatric presentations[25], while hot days predicted hospitalization for self-harm[26] and even suicide[27]. A link has also been found among Indian farmers between extreme heat, reduced agricultural yields and sharp increases in suicides[28].

Extreme weather events attributable to climate change can also lead to mental health risks if they provoke migration, whether people are forcibly displaced, resettled or choose to leave[29]. These risks are related to an array of factors connected with pre-migration vulnerability and post-migration adjustment. The features of and impacts on recipient communities, and the processes of interaction between migrants and their new communities, are also important: planned migration delivers superior outcomes[29,30]. Those forced to migrate often come from regions where rates of psychiatric morbidity and underlying mental health risk factors, such as violence and starvation, are high. A useful related literature therefore considers the severe mental health effects of climate change on sub-populations likely to be disproportionately vulnerable, such as migrants[29], women, youth[31] and people living with disadvantage, minority or ethnic status, poor family or social support and a history of mental illness[32]. Additionally, vital medicines and medical aids can be lost fleeing extreme weather events[33], interrupting continuity of care for people with pre-existing morbidity (especially among older adults[34]).

Informed by such studies, some authors have concentrated on the important issue of how climate change may stretch already inadequate mental health services[35,36] and considered how front-line healthcare workers, such as nurses[32] and pharmacists[37], can help fill local service gaps. The need to integrate the important role of disaster response personnel with that of other first responders[38], and their need for mental health training[39] given post-disaster mental health service requirements[40], has also been documented.

Complementing the epidemiological, clinical and health services contributions to understanding how climate change may affect population mental health are considerations of climate change's possible effect on individual cognition, affect and behaviour[41,42]. These considerations concur that climate change will increase the numbers of individuals exposed to extreme events and, therefore, to subsequent psychological problems[4] such as worry, anxiety, depression, distress, loss, grief, trauma and even suicide[43]. Opinion surveys across forty countries have confirmed that people are indeed worried about climate change[44], and a whole new 'science of loss' is emerging[45]. Worry and loss are important factors because they could be used to motivate community action on climate change[46], particularly

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Box 1 | Floods and mental health in an English case study

Climate change is likely to increase the risk of several types of flooding[117]. In the UK, it is estimated that mental health problems are responsible for 80% of all disability-adjusted life years attributable to floods[118], possibly conferring a greater burden than infectious disease and physical trauma. For example, a fourfold rise in psychological distress was found after flooding in southern England in 2004 (ref. [119]), with psychological effects persisting even four years post-flooding[120]. Thus, after widespread flooding in England in 2013–2014, a multi-year *National Study of Flooding and Health* has been established to examine the long-term impact of flooding on individuals living in flood-affected areas.

There are methodological complexities in measuring the mental health impacts of flooding, not least due to the variety of 'secondary stressors' which may affect individuals after such disasters, including lack of financial assistance, the process of insurance claims, and pressure on relationships[121]. Physical and psychological effects of flooding can be interlinked in complex ways[119], so collecting data on and adjusting for possible confounders was an essential component of the study design. In the first wave of data collection, twelve months after flooding, the prevalence of probable psychological morbidity was found to be elevated among flooded participants (depression 20.1%, anxiety 28.3%, PTSD 36.2%) and among those who were disrupted but had no floodwater entering their homes (depression 9.6%, anxiety 10.7%, PTSD 15.2%)[122]. Indeed, compared to those not flooded, flooded individuals had higher odds of depression (5.9), anxiety (6.5) and PTSD (>7) after adjusting for a range of factors.

Flooded participants who reported disruption to domestic utilities (such as electricity, gas or water) or to healthcare had higher odds of all mental disorders than did other flooded participants, as did those displaced from their homes. For example, adjusting for the depth and duration of floodwater in the home, the odds of probable depression were 1.7 times higher for participants who were displaced compared with those who were not[123]. The amount of warning received appeared to be a protective factor against psychological morbidity amongst the displaced: those receiving no warning before flooding tended to report more symptoms of depression and PTSD than those who were forewarned.

as climate change worry appears to be primarily experienced collectively rather than individually[47,48].

Overall, emerging thinking about climate change and mental health, together with a wealth of evidence on extreme events and their relation to psychiatric morbidity, have formed a solid base for understanding how climate change may affect future mental health. Welcome as this knowledge is, relationships among concepts have not been adequately analysed, theories of behavioural responses have not been tested[49], information has been lacking[50] and better evidence is urgently needed[8,51]. Moreover, there is a lack of insight into the difference in leverage achievable by individual compared to collective action and, thus, about the reasonable expectations of each. An emphasis on individual behaviour change is linked to neglect of social policy and collective action.

Need for systems thinking

When asked, individuals understandably take an egocentric, proximate view of how to survive tough times, relying on family and friends, being strong (for instance, applying humour and determination) and staying positive[52]. Advice from researchers, health departments and advocacy groups encourages this perspective, focusing primarily on what individuals can do to manage their own mental health. (This tendency has ballooned with the surge in popularity of health behavioural interventions[53].) Staying resilient and optimistic, doing positive things to cope, practising faith or mindfulness, making disaster kits and staying socially and culturally connected[54] have been advocated. Environmentally friendly mental health promotion guidelines have provided similarly individual-focused recommendations, encouraging people to have good home insulation, a weekly meat-free day, walk or cycle daily and drive within speed limits[55,66]. On the surface, these may seem sensible suggestions for people and planet. Indeed, certain physical activities[56] and healthier diets[57,58] containing fewer animal-based foods[59,60], reduce fossil fuel usage[61] and benefit mental health. The issue is that individual capacity to follow health-related advice is profoundly qualified by opportunity structures[9], social determinants[62] and service access, all of which are most deficient among those in greatest need[62,63].

It is essential to acknowledge the societal-level contexts and constraints[9] and the many feedback loops and reciprocities characterizing dynamic systems[64] and real lives. Individual capacity to make behavioural 'choices' is highly variable[65] and resources are skewed towards elites[66]. Indeed, most people (not just those living with disadvantage) cannot make all the 'choices' they want because they do not have the means or the opportunity. Take, for example, cycling enthusiasts, who tend to be employed, well-educated, well-off[67], physically active and living conveniently close to work[68]. Even among these fortunate individuals, for whom cycling for transport should be simple, opportunity structures disproportionately benefit the most highly-privileged: cycling for transport is easier for[69] and more common among[68] men than among women. We argue that, far from motivating whole-of-population behaviour change, individually focused interventions may be ineffectual even among the privileged few. Instead, participating in group-based ventures that emphasize identity, citizenship and the augmenting of social capital[70] will likely be more successful in shifting behavioural norms around mental health[9] and climate change. Thought leaders, including researchers, must look beyond the individual to understand what drives and constrains behaviour in whole populations[9].

Publications and reports about climate change and mental health, however, continue to emphasize clinical[71] and psychological perspectives, inflating the importance of individuals, proximate factors, symptoms and illness[72]. These shortcomings resonate with the general limitations of epidemiology[60], in that it focuses too much on the individual, on direct or proximate causes, on the past and present, and on current states of being; and too little on whole populations, indirect and distal influences, the lifecourse and the future, and the dynamics of health across contexts. This conceptual bias means that climate change and mental health research fails both to astutely decompose and to properly integrate vital facts about mental health, weather and climate change. Mental health is complicated and changeable, with outcomes sensitive to time, place and context[9], weather varies over seasons and years, and climates change over the short and long term.

To address this shortcoming, the study of climate change and mental health would benefit from systems thinking incorporating insights from a wide range of disciplines. We define systems thinking as a set of 'synergistic analytic skills' used to help describe a complex set of interacting factors that produce outcomes, to predict their behaviour and to formulate interventions to achieve desired (and avoid pernicious) results[63]. This definition incorporates activities such as: identifying key concepts, their interconnections and feedback loops; understanding the structure of the system as a whole and at different scales; characterizing its dynamic behaviour; describing its inherent resources (such as infrastructure, money or trust) and how these change over time and context; revealing non-linear relationships; and using analysis to reduce complexity and generate insights. The term 'system' in the present context encompasses all the geopolitical, socioeconomic, ecological and

environmental factors that impinge on mental health, including but certainly not limited to the 'health system' itself.

Like all systems, the climate-change–mental-health system has power, resilience and momentum, producing mental health outcomes which, within a certain range of tolerance, are unavoidable. This is because human systems are embedded in, reflective of and shaped by societal norms and priorities. These norms do not wholly determine individuals' circumstances but they profoundly shape population outcomes[9]. This is why systems thinking is so important for public policy decision-making. Understanding a system helps decode complexity, allowing possible consequences of decisions to be simulated and examined. This can guide how political narratives are framed and policy proposals explained, optimizing public acceptance of unpopular decisions whose benefit to mental health may not initially seem obvious (such as closing coal mines, curbing private car usage or taxing red meat). Systems thinking also helps with the important task of identifying a priori where interventions may fail, costs exceed benefits or perverse outcomes eventuate[9]. To return to the cycling example, cycling for transport really is sensible, yet insufficiently insightful decision-making might inadvertently channel public investment disproportionately towards males, aggravating gender disparities[73–75]. An important benefit of systems thinking for climate change and mental health is that it can help align the needs of this emerging field with existing policy, research and agendas.

A preliminary causal process diagram

Systems thinking will be beneficial for organizing and interpreting the large and diverse body of information relevant to climate change and mental health. Systematic reviews can be used to identify unique factors and their causal linkages to be used as inputs into describing the system. The many connections and reciprocities between factors can be conveniently represented diagrammatically to help reveal how the system works and to formulate research questions and policy options. As an illustration, Vins et al.[76] identified several different pathways linking drought to mental health (such as a socio-economic pathway, highlighted in Fig. 1).

Building on previous work[13,19,30,46,66,77–81], Fig. 2 is a simplified depiction of the broad climate-change–mental-health harm system, showing how climate change catalyses a series of reactions which separately and interactively exacerbate risks to mental health and well-being. (Separate diagrams are needed for how climate change could be used to benefit mental health.) Indeed, climate change is itself a result of an underlying systemic drivers: unethical conduct by governments and big business has produced multiple international dilemmas, including unchecked human-induced climate change. We identify six core concepts relating climate change to mental health, embracing distal through intermediate to proximate factors, each of which influences the next in the chain. Thus, (i) unethical conduct by governments and big business has (ii) aggravated the root causes of mental illness which include climate change. One outcome of climate change is the occurrence of more frequent weather-related disasters such as heatwaves, floods and droughts. These disasters generate (iii) widespread destruction and upheaval to people and place and (iv) put pressure on multiple domains of public resources, including those related to health. This eventually (v) strains community functioning. Resultant deterioration of individuals' personal material and emotional resources (vi) stresses mental health and well-being, ultimately increasing the likelihood of mental illness.

Each of these six core concepts contains its own sub-system of dynamically linked factors (each inter-related in complex ways). Figure 2 incorporates some of the factors that will interact to stress personal resources (the shaded area labelled 'A'), to create widespread upheavals ('B') and to put pressure on public resources ('C'). The shaded area 'D' illustrates how mediating proximate factors arise from and link the major concepts to mental illness. The presence

of underlying vulnerability or resilience moderates the likelihood that risk factors and exposures will result in mental illness for a given individual.

Future directions

As the World Health Organization's Comprehensive Mental Health Action Plan 2013–2020 (ref. [8]) identifies, there is a huge unmet global need for more and better mental health support. The plan stresses that promotion and prevention, supported by research, will be vital in helping address this. However, this is only one dimension of the required expansion in research effort, an enterprise that faces many of the difficulties raised in criticisms of conventional epidemiology[82]. A first task is thus to develop a systems-thinking-based research plan which can help articulate sensible co-research topics and indicate important interdependencies to be examined (as sketched in Fig. 2 by the shaded areas). As an example, in Europe, it has been estimated that climate change may produce a ten-fold increase in the costs of critical infrastructure damage by 2100 (ref. [83]). Using Fig. 2, we can see that infrastructure damage diverts resources from public health, requires increased taxation, damages societal functioning and puts pressure on individual resources, all of which ultimately influence mental health. Protecting critical infrastructure is, therefore, an important mental health promotion strategy that may not have been easily discernible without systems thinking.

To result in effective action, the research plan must be constructed as a community–policy–research endeavour and generate rich detail about each concept and relationship. This difficult but essential preliminary task is time-consuming, requiring strategically selected systematic reviews to produce separate diagrams depicting: pathways for harm; opportunities and co-benefits arising from mitigation and adaptation actions; and representations of the idiosyncratic or additional barriers faced by women and disenfranchised minorities, and variations by country setting and urban–remote contrasts. Box 2 lists core components to be incorporated into such a plan. Realizing this research agenda requires the support of a globally credible coordinating institution, such as an internationally respected university with evident commitment to this research domain. It also needs substantial long-term funding (funding bodies must do better) and a core 'home' project, such as the Lancet Countdown, which was established to track global progress on health and climate change through international multidisciplinary research collaboration between academic institutions and practitioners.

Required research and methods

We will now evaluate the types of research and research methods that are required to redress the shortcomings of conventional epidemiology. We conclude that systems thinking and relevant analytic techniques offer the most promising approach.

Measuring the burden of disease and how it is changing over time. This calls for quantitative studies — particularly large, longitudinal population health studies and studies from world regions, continents, countries and local places yet to contribute. It will be important to support nations with limited capacity to participate[84], especially those most affected by and least responsible for climate change[6]. Also essential is the development of global and national indicators to measure progress in tackling the effects of climate change on mental health from a systems perspective. This is the purpose of the Lancet Countdown, which has begun the process of incorporating indicators for mental health[85]. But burden of disease is not a simple concept, especially for mental health, and a systems perspective will inform the many choices required concerning disease definitions, sub-populations to assess separately, and how to understand trends in burden of disease in relation to systemic societal contributors to disease[86].
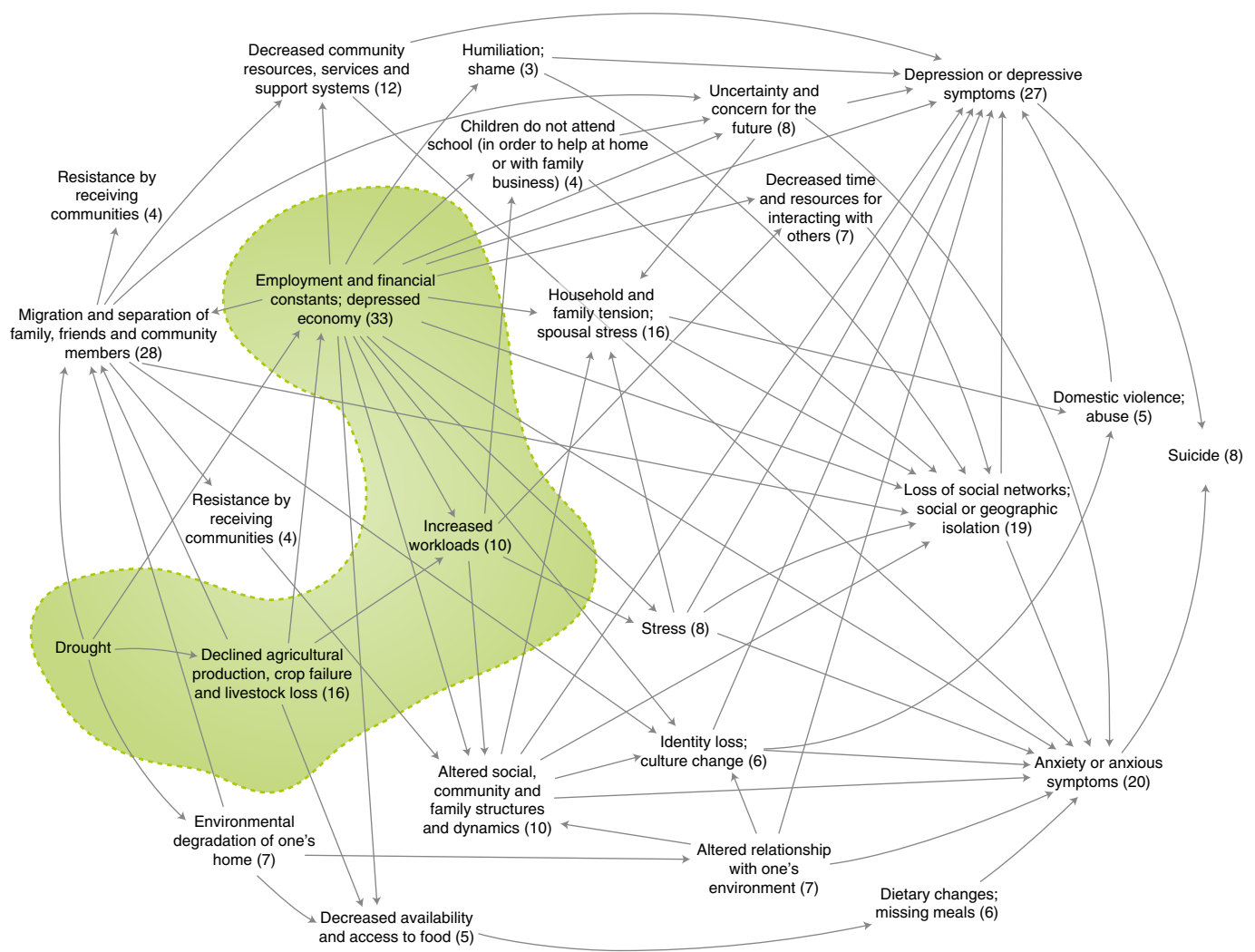
Fig. 1 | Causal process diagram for the mental health effects of drought based on a systematic review. Numbers in brackets indicate the quantity of papers meeting the search criteria located for each factor. The shaded area shows how the systems diagram can be used to isolate meaningful sub-systems for research and analysis, in this case, drought-related socio-economic factors and pathways that ultimately affect mental health. Adapted from ref. [73] (MPDI).

Because of the complexity of the causal networks involved, the systems thinking approach will come into its own particularly in understanding how and why climate and climate change affect mental health (aetiology). Climate change itself is (largely) an exposure of the future, even though the world is already witnessing some conspicuous impacts. Although health impacts of extreme weather are measurable, attributing them to climate change is problematic because the range of exposures is still, for the most part, within the range of normal variation, merely appearing more often. It is also difficult to know which potential adaptation and mitigation strategies to build into predictive models, and how to do so. Systems thinking can help find ways around problems such as these. For example, some of the indirect effects of climate change (explicated in causal process diagrams), such as heat-related increases in violence, are already impacting individuals and populations and these can be measured, providing parameter estimates for inclusion in systems models. Conventional analytic epidemiologic studies are limited to investigating a small subset of these pathways: those involving outcomes measurable in individuals, in short timeframes and in response to acute exposures, such as extreme weather events. Unravelling effects that operate at the population level, in indirect ways and across the entire lifecourse, demands different approaches.

Experimental epidemiology, with intervention studies at levels from the individual to national (and, ideally, eventually international) is needed to gather insights and creative ideas for long-term climate change adaptation that can evolve as circumstances change, including for target sub-populations and locations. Qualitative studies will play an important role in deeply understanding these fine-grained subtleties, and local empirical studies are already providing useful insights. Initially small, then larger, experimental climate change mitigation and adaptation intervention studies can be undertaken to learn what works and what might be sustainable over the long term and for large numbers of people. Because of the long timeframe of climate impacts, dynamic systems models and agent-based models[73,87] may be valuable for testing interventions in simulated settings. They could also help with the vital task of promoting consistency in approaches, methods and measures to potentially allow larger scale quantification.

Systems approaches, equally, can be applied in designing intervention studies. The WHO has stressed[74] the importance of 'knowing the system' before designing interventions and evaluations. This applies to any particular disease group as well as to entire health systems, and systems thinking has been applied in several specific

a

Impaired capacity to cope

Less social support

Reduced social cohesion

Reduced community participation

Loss of positive identities

Isolation

(i) Unethical conduct by governments and big business

b

Interruptions to public transport

Food shortages

Power, energy and connectivity lost

Sacred sites and special places damaged

Homes and businesses destroyed

Harm to land and agriculture

(vi) Loss of personal (mental health) resources

(ii) Aggravation of root causes of mental illness

Damage to outdoor natural and recreational resources

Elevated risks to mental health and wellbeing

Climate change

Damaged public infrastructure

Forced displacement

(v) Pressure on societal and community functioning

(iii) Widespread destruction and upheavals

Individual vulnerability and resilience

c

Costs of reconstruction and recovery

d

Physical injury

Health workforce shortages

Increased taxation

Pressure on frontline responders

(iv) Pressure on public (health-related) resources

Medications lost or ineffective

Poor nutrition

Psychiatric trauma

Pressure on health systems

Reduced physical activity
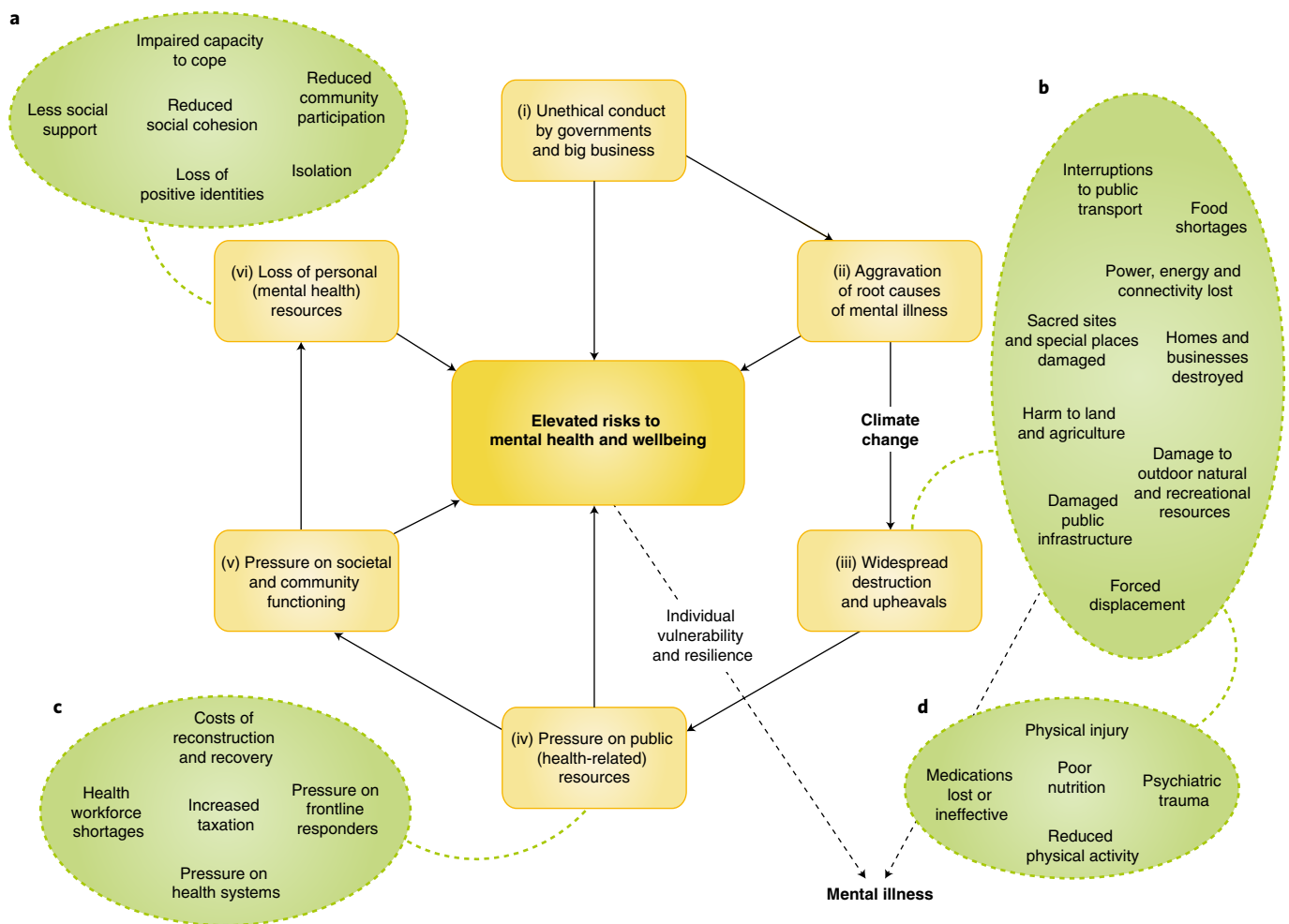
Mental illness

Fig. 2 | Top-level causal process diagram showing major domains of distal, intermediate and proximate harm linking climate change and mental illness. Each domain affects the next and, through various proximate mediators, also independently elevates mental health risk. **a**, Factors that interact to produce loss of personal resources. **b**, Factors that interact to produce widespread destruction and upheavals. **c**, Factors that interact to produce pressure on public (health-related) resources. **d**, An example of proximate mediators that lie on sub-system pathways connecting particular domains to mental illness. Individuals' underlying vulnerability (or resilience) increases (or decreases) the risk of mental illness as a consequence of climate-change-related exposures (dotted lines).

areas (such as tobacco control, obesity and tuberculosis). Because of its inherent complexity and the importance of distal, life-course influences, mental health is a field where systems thinking would be particularly valuable. Being so complex, the climate-change–mental-health system needs a top-level framework (that is, Fig. 2) within which more detailed analyses for particular types of threats could be nested.

Population projections. These will be important for calculating rates of unwellness and associated health system demand. Such projections are needed so that we know better what to expect and can plan more strategically, equip ourselves with a good understanding of planned (and possibly perverse) outcomes, invest where we will get optimal impact, and be pragmatic, flexible and creative. Population projections have become prominent in the context of all kinds of climate change impacts, not just health. In this context, it combines quantitative climate projections from climate science with estimates of climate–health response functions from experimental and observational studies. Quantitative systems approaches, especially scenario modelling, may be applicable here.

Data and analytic methods. The systems approach includes a wide variety of methods[75] and tools, which call for different data types to support them[64]. In this context, network analysis will serve primarily as a qualitative concept-raising step, setting the scope of agent-based and dynamic models. Scenario modelling from climate science describes the exposures that must be considered in rich meteorological, geographical and temporal detail. It is important to recognize that considerable variation in climate-change-related vulnerability exists within as well as between countries[88], and these must also be modelled. The applications of data-driven analysis will be in determining the quantitative parameters of agent-based and dynamic models, and it is these that will determine the types of data required. Data sources may be both direct (for example, daily count of emergency calls and responses to weather-related disasters, and comparisons of acts of violence comparing periods of normal and extreme weather) and indirect (for example, insurance industry data, including internal financial modelling and associated decisions about policy premiums which are based on detailed actuarial analyses of the likelihood and impact of extreme events). Ministries of defence incorporate similar considerations into their strategic and disaster planning and so their budget allocations may be informative.

Box 2 | Components of a research agenda for climate change and mental health

To establish the needed research effort in climate change mental health, it will first be necessary to negotiate a research agenda that is researcher-led and developed jointly with policy actors, civil society and service providers. An appropriate home institution and suitable umbrella project will also be needed, along with an integrated international research capacity development programme. Funders must be asked to back large-scale, complex, exploratory projects requiring many disciplinary perspectives and very strong co-generation of knowledge. This will demand genuine risk and failure tolerance and investment in research governance and leadership training. Vitally, funders must progress from counting project outputs to evaluating outcomes-oriented performance. These initiatives must themselves be understood, valued and properly supported. With these matters in mind, the following components are proposed for inclusion in a new research agenda.

Develop and test strategies for rapid and effective political and policy engagement to support climate change mitigation and adaptation. Include mechanisms to:

- Ensure the equal inclusion of women and people from countries and locations most affected by climate change in leadership and decision-making
- Listen to the voices of minorities, especially those of Indigenous peoples, and take account of their wishes and unique knowledge

Understand the component parts of the climate change and mental health system. Undertake systematic reviews of:

- The relationships between climate change, specific climate-change-related extreme events and mental health and well-being (for example, understand the 'climate-change–heatwaves–mental-health' system)
- The ways in which important moderators (for example, gender, level of country development, indigeneity, life stage, minority group membership, urbanicity–remoteness, ethnicity, poverty, and existing health status) interact with the climate change and mental health system, or with its component parts

- Pathways of benefit as well as of harm

Describe the entire climate change and mental health system using a research–policy–community co-design approach:

- Identify, construct and test detailed causal process diagrams for self-contained components of the system
- Over time, construct and test an understanding of the whole system
- Describe the policy and programme implications of each part of the system and identify key leverage points for promoting improved mental health
- Describe the effects different approaches to mitigation and adaptation might have on the whole system and on its important components; identify consequences for mental health and propose pilot intervention studies

Initiate small, prototype-testing group-level intervention studies to promote well-being and to improve prevention and early intervention in climate change-related mental health and well-being:

- Experiment with projects in various group-level settings, such as neighbourhoods, workplaces, schools, online communities, corporate head offices and households
- Develop and test approaches for individual-level and, especially, community-level interventions, including for disadvantaged groups
- Engage with international projects, such as the Lancet Countdown on Health and Climate Change, to track and measure the impacts of climate change on mental health and well-being
- Invest in developing and adapting a full range of existing and new research approaches and methods to investigate climate change and mental health
- Establish processes for motivating climate change and mental health research and new ways of acknowledging contributions and promulgating core research findings, such as international awards for outstanding research and leadership achievements

Geographic information systems. Climate change projections are now available at small-area level and this has potentiated the use of geographic information systems in post-disaster mental health research. Studies have identified spatial clustering of post-disaster risk and resilience[89], wellness[90] and long-term unemployment[91]. GIS modelling can thus be used to model dynamic relationships over time and contexts, and could be applied in systems-thinking-based climate change and mental health research.

Politics, policy and diplomacy. These might not seem to be climate-change-related mental health research considerations, but they are the source of and potential solution to the root causes of mental illness and well-being[9,72]. Political will to address climate change is missing, manipulated by the small but influential cadre of persistent climate change deniers[44,92]. Tellingly, political will is in itself important for well-being, perhaps because it reflects the societal norms and priorities which influence mental health outcomes[9]. For example, European 'eco-states' (defined as those which take climate change seriously and accord it a central role in policy) have lower rates of mental disorders than do neighbouring countries[93]; and countries with right-leaning governments (influenced by conservative think-tanks which tend to oppose climate action[94]) have higher rates of suicide than do their left-leaning neighbours[95–97].

Systems thinking and arising analyses can reveal how ideology, politics and diplomacy connect to policy decision-making and, ultimately, to the well-being of nations. It can help demonstrate why a different kind of framework (one that addresses the big societal questions of equitable, sustainable global progress) must become the guiding light for new approaches to research. Such approaches are essential to making progress in mental health[9]. Relevant and well thought-through frameworks are increasingly available internationally (for example, the *Canadian Index of Wellbeing*[98], *The Australia We Want*[99], the OECD societal progress framework[100] and *The Wales We Want*, which even has its own legislation[101]). These provide suitable philosophical and practical structures for thinking about climate change, about how people perceive fairness in this context[102] and about mental health.

A new style of research leadership
The co-production of knowledge and policy is essential to developing appropriate action for climate change and mental health and for achieving the necessary political buy-in. Writing about urban health, Lawrence and Gatzweiler[103] proposed creating and adopting a "transdisciplinary knowledge domain" based on "admitting rather than denying complexity and radical uncertainty". Their framework is relevant here, and would see academic researchers controlling research methodology, while "the definition and

analysis of the research questions and the dissemination of results are done jointly with other non-academic representatives of society". Joint research-policy-me teams are thus essential to continuously evolving shared knowledge and understanding, and to preventing a research 'translation' problem[104] from developing. Adopting a systems approach helps explain why climate change and mental health research must be tackled by multiple actors, and why they must use many academic disciplines, all working towards jointly agreed long-term goals.

But for many research leaders, creating, directing and managing complex co-research projects will be a substantial intellectual and practical challenge for which they feel (and often are) ill-equipped. Few have been trained for the task (unless they have had prior experience in industry[105]) and many will need professional development in strategic planning, governance, management, public engagement and the politics of policy-making. In many regions and countries, lack of democracy and educational opportunity and extensive corruption militate against excellence[106]. This includes academic corruption, which is not systematically managed[107,108]. Widespread inequality and, specific to research, incompetent recruitment decisions[109], lack of research funding, and inadequate capacity-building, also constrain excellence. Persistent nepotism among influential professional groups[110,111] also contributes. Current clinical leadership development programmes are inadequate, commonly targeting junior staff and incorporating few senior leadership skills[112], and willingness among academics to assume leadership roles is most common among inexperienced faculty exploring career advancement opportunities[113]. Appropriately qualified management consultants could help deliver senior leadership development interventions[105] teaching vision, strategy and planning, management styles and the soft skills of team and personal development[114]. The extent to which top-level university decision-makers understand and commit to actively supporting required changes will determine the success of the needed research leadership transformation.

Conclusion

International effort to reduce global warming has been far too little, far too late and the world (mainly, the underprivileged world) now has to bear the consequences of this reckless inaction. Delineating the climate-change–mental-health system makes it impossible to ignore that the association between disasters, disadvantage and compromised mental health is no coincidence, and that those in positions of influence must not look the other way[115]. Immediate vigorous mitigation could still prevent catastrophic warming. Many of the actions required to do this, and to adapt, could promote mental well-being and minimize harm. Individuals have a degree of personal control and, consequently, can reasonably be asked to take some personal responsibility for acting. But any such expectations must be understood in terms of how strongly complexes of factors influence scope for individual 'choice'.

Systems thinking, which describes the big picture as well as the detail[116], can be used to help drive ideas towards the radical action needed. Our proposed framework incorporates crucial elements to integrate into delineating the climate-change–mental-health system, indicates important relationships among these elements and demonstrates how to select sensible reciprocities and subsystems for research-policy projects. Just as mental health needs whole person, whole community, whole of life research-policy approaches, so mental health in the context of climate change needs 'whole person, whole community, whole of life, whole of planet' strategies, aimed at achieving sustainable well-being for people and place. With its complexity and sensitivity, mental health could be a lead indicator for measuring progress on mitigating the human impacts of climate change.

References

1. McMichael, A. J., Berry, H. L. & Butler, C. D. IPCC Impacts report: Staring into the abyss. *World Nutrit.* **5**, 432–435 (2014).
2. Costello, A. et al. Managing the health effects of climate change. *Lancet* **373**, 1693–1733 (2009).
3. McMichael, A. J. Insights from past millennia into climatic impacts on human health and survival. *Proc. Natl Acad. Sci. USA* **109**, 4730–4737 (2012).
4. Padhy, S. K., Sarkar, S., Panigrahi, M. & Paul, S. Mental health effects of climate change. *Indian J. Occup. Environ. Medic.* **19**, 3–7 (2015).
5. Im, E. S., Pal, J. S. & Eltahir, E. A. B. Deadly heat waves projected in the densely populated agricultural regions of South Asia. *Sci. Adv.* **3**, e1603322 (2017).
6. Amegah, A. K., Rezza, G. & Jaakkola, J. J. Temperature-related morbidity and mortality in Sub-Saharan Africa: A systematic review of the empirical evidence. *Environ. Int.* **91**, 133–149 (2016).
7. Pal, J. S. & Eltahir, E. A. B. Future temperature in southwest Asia projected to exceed a threshold for human adaptability. *Nat. Clim. Change* **6**, 197–200 (2016).
8. *Mental Health Action Plan 2013–2020* (WHO, 2013).
9. Compton, M. T. & Shim, R. S. The social determinants of mental health. *FOCUS* **13**, 419–425 (2015).
   A comprehensive summary and interpretation of how opportunity structures profoundly shape mental health.
10. Green, D. et al. Advancing Australia's role in climate change and health research. *Nat. Clim. Change* **7**, 103–106 (2017).
11. Gifford, E. & Gifford, R. The largely unacknowledged impact of climate change on mental health. *Bull. Atom. Sci.* **72**, 292–297 (2016).
12. Stanke, C., Murray, V., Amlôt, R., Nurse, J. & Williams, R. The effects of flooding on mental health: Outcomes and recommendations from a review of the literature. *PLoS Curr. Disasters* http://doi.org/cksw (2012).
13. Berry, H. L., Bowen, K. & Kjellstrom, T. Climate change and mental health: A causal pathways framework. *Int. J. Public Health* **52**, 123–132 (2010).
14. Ding, N., Berry, H. L. & O'Brien, L. V. The effect of extreme heat on mental health — Evidence from Australia. *Int. J. Epidemiol.* **44**, i64 (2015).
15. Obradovich, N., Migliorini, R., Mednick, S. C. & Fowler, J. H. Nighttime temperature and human sleep loss in a changing climate. *Sci. Adv.* **3**, e1601555 (2017).
    A convincing empirical demonstration of how climate change may affect important determinants of mental health (in this case, disturbed sleep).
16. Robotham, D. Sleep as a public health concern: Insomnia and mental health. *J. Public Ment. Health* **10**, 234–237 (2011).
    An analysis of a poorly addressed but important climate-change-relevant concept explaining the ways mental health and insomnia affect each other.
17. Cusack, L., de Crespigny, C. & Athanasos, P. Heatwaves and their impact on people with alcohol, drug and mental health conditions: A discussion paper on clinical practice considerations. *J. Adv. Nursing* **67**, 915–922 (2011).
18. Mora, C. et al. Global risk of deadly heat. *Nat. Clim. Change* **7**, 501–506 (2017).
    A compelling and alarming analysis of heatwave-related mortality and the numbers of human lives that may be lost in coming decades due to climate change.
19. Ding, N., Berry, H. L. & Bennett, C. M. The importance of humidity in the relationship between heat and population mental health: Evidence from Australia. *PLOS ONE* **11**, e0164190 (2016).
20. Vida, S., Durocher, M., Ouarda, T. B. M. J. & Gosselin, P. Relationship between ambient temperature and humidity and visits to mental health emergency departments in Québec. *Psych. Serv.* **63**, 1150–1153 (2012).
21. Knapp, P. A., Maxwell, J. T., Ortegren, J. T. & Soulé, P. T. Spatiotemporal changes in comfortable weather duration in the continental United States and implications for human wellness. *Ann. Am. Assoc. Geogr.* **106**, 1–18 (2016).
22. Hansen, A. et al. The effect of heat waves on mental health in a temperate Australian city. *Environ. Health Persp.* **116**, 1369–1375 (2008).
23. Noelke, C. et al. Increasing ambient temperature reduces emotional well-being. *Environ. Res.* **151**, 124–129 (2016).
24. Trang, P. M., Rocklöv, J., Giang, K. B., Kullgren, G. & Nilsson, M. Heatwaves and hospital admissions for mental disorders in Northern Vietnam. *PLoS ONE* **11**, e0155609 (2016).
25. Nitschke, M., Tucker, G. R. & Bi, P. Morbidity and mortality during heatwaves in metropolitan Adelaide. *Medical J. Aus.* **187**, 662–665 (2007).
26. Williams, M. N., Hill, S. R. & Spicer, J. Do hotter temperatures increase the incidence of self-harm hospitalisations? *Psych. Health Medic.* **21**, 226–235 (2015).

27. Qi, X., Hu, W., Mengersen, K. & Tong, S. Socio-environmental drivers and suicide in Australia: Bayesian spatial analysis. *BMC Public Health* **14**, 681 (2014).

28. Carleton, T. A. Crop-damaging temperatures increase suicide rates in India. *Proc. Natl Acad. Sci. USA* **114**, 8746–8751 (2017).

29. McMichael, C., Barnett, J. & McMichael, A. J. An ill wind? Climate change, migration, and health. *Environ. Health Persp.* **120**, 646–654 (2012).

30. McMichael, A. J., McMichael, C. E., Berry, H. L. & Bowen, K. In *Climate Change and Displacement: Multidisciplinary Perspectives* (ed. McAdam, J.) 191–220 (Hart Publishing, Oxford, 2010).

31. Whiteford, H. A., Ferrari, A. J., Degenhardt, L., Feigin, V. & Vos, T. The global burden of mental, neurological and substance use disorders: An analysis from the global burden of disease study 2010. *PLoS ONE* **10**, e0116820 (2015).

32. Trombley, J., Chalupka, S. & Anderko, L. Climate change and mental health. *Am. J. Nursing* **117**, 44–52 (2017).
    An elegant rehearsal and action-oriented summary of the ways in which climate change may affect a broad selection of mental health problems and how nursing may contribute to managing these effects.

33. Ochi, S., Hodgson, S., Landeg, O., Mayner, L. & Murray, V. Disaster-driven evacuation and medication loss: A systematic literature review. *PLOS Curr. Disasters* http://doi.org/cksx (2014).

34. Nitschke, M. et al. Risk factors, health effects and behaviour in older people during extreme heat: A survey in South Australia. *Int. J. Environ. Res. Public Health* **10**, 6721–6733 (2013).

35. Blashki, G. A. et al. Preparing health services for climate change in Australia. *Asia Pacific J. Public Health* **23**, 133–143 (2011).

36. Blashki, G. A., Berry, H. L. & Kidd, M. J. In *Climate Change and Social Justice* (ed. Moss, J.) 144–167 (Melbourne University Press, Melbourne, 2009).

37. Davidson, I., Fleming, L. E., Redshaw, C. H., Depledge, M. H. & Stahl-Timmins, W. Time to act: Pharmacists must be prepared for environmental changes. *Pharmac. J.* **292**, 545 (2014).

38. Reifels, L. et al. Lessons learned about psychosocial responses to disaster and mass trauma: An international perspective. *Eur. J. Psychotraumatol.* **4**, 22897 (2013).
    A wide-ranging consideration by disaster response experts of how best to plan and deliver post-disaster psychosocial interventions.

39. Reifels, L. et al. A systematic approach to building the mental health response capacity of practitioners in a post-disaster context. *Adv. Mental Health* **11**, 246–256 (2013).

40. Reifels, L. et al. Patterns and predictors of primary mental health service use following bushfire and flood disasters. *Eur. J. Psychotraumatol.* **5**, 26527 (2014).

41. Doherty, T. J. & Clayton, S. The psychological impacts of global climate change. *Am. Psychol.* **66**, 265–276 (2011).

42. Swim, J. et al. Psychology and global climate change: Addressing a multi-faceted phenomenon and set of challenges. *Am. Psych.* **66**, 181–193 (2011).

43. Majeed, H. & Lee, J. The impact of climate change on youth depression and mental health. *Lancet Planet. Health* **1**, e94–e95 (2017).

44. Stokes, B., Wike, R. & Carle, J. *Global Concern about Climate Change, Broad Support for Limiting Emissions; US, China Less Worried; Partisan Divides in Key Countries* (Pew Research Centre, 2015).

45. Barnett, J., Tschakert, P., Head, L. & Adger, W. N. A science of loss. *Nat. Clim. Change* **6**, 976–978 (2016).

46. Berry, H. L. Pearl in the oyster: Climate change as a mental health opportunity. *Aus. Psych.* **17**, 453–456 (2009).

47. Berry, H. L. & Peel, D. Worrying about climate change: Is it responsible to promote public debate? *British J. Psych. Int.* **12**, 31–32 (2015).

48. Searle, K. & Gow, K. Do concerns about climate change lead to distress? *Int. J. Clim. Change Strateg. Manage.* **2**, 362–379 (2010).

49. Ejeta, L. T., Ardalan, A. & Paton, D. Application of behavioral theories to disaster and emergency health preparedness: A systematic review. *PLOS Curr. Disasters* http://doi.org/cks2 (2015).
    A useful discussion of how to select and apply behavioural theories to an example of climate change adaptation.

50. Brisley, R., Welstead, J., Hindle, R. & Paavola, J. *Socially Just Adaptation to Climate Change: An Exploration of How Far Social Justice is Considered in Local Adaptations to Climate Change Impacts across the UK* (Joseph-Rowntree Foundation, York, 2012).

51. *Climate Change and Health Fact Sheet* (World Health Organization, 2017).

52. Taylor, M. et al. Psychosocial stress and strategies for managing adversity: Measuring population resilience in New South Wales, Australia. *Popul. Health Metr.* **8**, 28 (2010).

53. Holman, D., Lynch, R. & Reeves, A. How do health behaviour interventions take account of social context? A literature trend and co-citation analysis. *Health* http://doi.org/cks3 (2017).

54. Clayton, S., Manning, C. M., Krygsman, K. & Speiser, M. *Mental Health and Our Changing Climate: Impacts, Implications, and Guidance* (American Psychological Association, ecoAmerica, 2017).

55. Nurse, J., Basher, D., Bone, A. & Bird, W. An ecological approach to promoting population mental health and well-being — A response to the challenge of climate change. *Persp. Public Health* **130**, 27–33 (2010).
    An interesting analysis of how to promote mental health in its broad socio-environmental context in the face of climate change without further damaging the environment.

56. White, R. L. et al. Domain-specific physical activity and mental health: A meta-analysis. *Am. J. Prevent. Med.* **52**, 653–666 (2017).

57. Jacka, F. N. et al. A randomised controlled trial of dietary improvement for adults with major depression (the 'SMILES' trial). *BMC Med.* **15**, 23 (2017).
    A convincing, well-controlled early empirical study in the important emerging field of nutritional psychiatry.

58. Sarris, J. et al. Nutritional medicine as mainstream in psychiatry. *Lancet Psych.* **2**, 271–274 (2015).

59. Springmann, M., Godfray, H. C. J., Rayner, M. & Scarborough, P. Analysis and valuation of the health and climate change cobenefits of dietary change. *Proc. Natl Acad. Sci. USA* **113**, 4146–4151 (2016).

60. Raphaely, T. & Marinova, D. Flexitarianism: Decarbonising through flexible vegetarianism. *Renew. Energy* **67**, 90–96 (2014).

61. Obradovich, N. & Fowler, J. H. Climate change may alter human physical activity patterns. *Nat. Hum. Behav.* **1**, 0097 (2017).

62. Manderscheid, R. W. et al. Evolving definitions of mental illness and wellness. *Prevent. Chronic Dis.* **7**, A19 (2010).

63. Collins, P. Y. et al. Grand challenges in global mental health: A consortium of researchers, advocates and clinicians announces here research priorities for improving the lives of people with mental illness around the world, and calls for urgent action and investment. *Nature* **475**, 27–30 (2011).

64. Diez Roux, A. V. Health in cities: Is a systems approach needed? *Cadernos Saude Publica* **31**(suppl. 1), 9–13 (2015).

65. Malkina-Pykh, I. G. & Pykh, Y. A. An integrated model of psychological preparedness for threat and impacts of climate change disasters. *Disast. Manage. Human Health Risk III* **133**, 121–132 (2013).

66. Berry, H. L. Social capital elite, excluded participators, busy working parents and aging, participating less: types of community participators and their mental health. *Soc. Psych. Psych. Epidemiol.* **43**, 527–537 (2008).

67. Sahlqvist, S. & Heesch, K. C. Characteristics of utility cyclists in Australia: an examination of the associations between individual, social and environmental factors and utility cycling. *J. Phys. Activ. Health* **9**, 818–828 (2012).

68. Engbers, L. H. & Hendriksen, I. J. M. Characteristics of a population of commuter cyclists in the Netherlands: Perceived barriers and facilitators in the personal, social and physical environment. *Int. J. Behav. Nutrit. Phys. Activ.* **7**, 89–89 (2010).

69. Heesch, K. C., Sahlqvist, S. & Garrard, J. Gender differences in recreational and transport cycling: A cross-sectional mixed-methods comparison of cycling patterns, motivators, and constraints. *Int. J. Behav. Nutrit. Phys. Activ.* **9**, 106 (2012).

70. van Kasteren, Y. How are householders talking about climate change adaptation? *J. Environ. Psychol.* **40**, 339–350 (2014).

71. Casstevens, W. J. Social work education on mental health: Postmodern discourse and the medical model. *J. Teach. Soc. Work* **30**, 385–398 (2010).
    A thought-provoking analysis of how the western-style medical model serves to benefit and frustrate the promotion of health and well-being, including its excessive focus on the individual.

72. Nigatu, A. S., Asamoah, B. O. & Kloos, H. Knowledge and perceptions about the health impact of climate change among health sciences students in Ethiopia: A cross-sectional study. *BMC Public Health* **14**, 587 (2014).

73. Amelung, B. et al. The value of agent-based modelling for assessing tourism-environment interactions in the Anthropocene. *Curr. Opin. Environ. Sustain.* **23**, 46–53 (2016).

74. Savigny, D.d. & Taghreed, A. (eds) *Systems Thinking for Health System Strengthening* (World Health Organization, 2009).

75. Peters, D. H. The application of systems thinking in health: Why use systems thinking?. *Health Res. Policy Syst.* **12**, 51 (2014).
    A useful introduction to why and how systems thinking can be used to improve health-related research, policy and practice.

76. Vins, H., Bell, J., Saha, S. & Hess, J. The mental health outcomes of drought: A systematic review and causal process diagram. *Int. J. Environ. Res. Public Health* **12**, 13251 (2015).
    A thorough, orderly identification of the concepts pertaining to drought and mental health and a clear explication of the complex and reciprocal pathways linking them.

77. Berry, H. L. et al. Mind, body, spirit: Co-benefits for mental health from climate change adaptation and caring for country in remote Australian Aboriginal communities. *NSW Bull. Public Health* **21**, 5–6 (2010).

78. Berry, H. L., Hogan, A., Owen, J., Rickwood, D. & Fragar, L. Climate change and farmers' mental health: Risks and responses. *Asia Pacific J. Public Health* **23**, S119–132 (2011).

79. Berry, H. L. & Welsh, J. A. Social capital and health in Australia: An overview from the Household Income and Labour Dynamics in Australia Survey. *Soc. Sci. Medic.* **70**, 588–596 (2010).

80. McDermott, B., Berry, H. L. & Cobham, V. Social connectedness: A new aetiological factor in the development of child Posttraumatic stress disorder. *Aus. New Zealand J. Psych.* **46**, 109–117 (2012).

81. O'Brien, L. V., Berry, H. L., Coleman, C. & Hanigan, I. Drought as a mental health exposure. *Environ. Health* **131**, 181–187 (2014).

82. McMichael, A. J. Prisoners of the proximate: Loosening the constraints on epidemiology in an age of change. *Am. J. Epidemiol.* **149**, 887–897 (1999). **A seminal critique of the failings of modern epidemiology, the consequences of these failings and the future directions needed to improve this scientific field.**

83. Forzieri, G. et al. Escalating impacts of climate extremes on critical infrastructures in Europe. *Glob. Environ. Change* **48**, 97–107 (2018).

84. Expanding research views. *Nat. Clim. Change* **7**, 229 (2017).

85. Watts, N. et al. The Lancet Countdown on health and climate change: From 25 years of inaction to a global transformation for public health. *Lancet* (in the press).

86. *More Than Just Numbers: Exploring the Concept of "Burden of Disease"* (NCCID, Winnipeg, 2016).

87. Auchincloss, A. H. & Diez Roux, A. V. A new tool for epidemiology: The usefulness of dynamic-agent models in understanding place effects on health. *Am. J. Epidemiol.* **168**, 1–8 (2008).

88. Hallegatte, S. & Rozenberg, J. Climate change through a poverty lens. *Nat. Clim. Change* **7**, 250–256 (2017). **An absorbing and challenging analysis of how a key determinant of mental health (i.e., poverty) amplifies the risks and impacts of climate change.**

89. Gruebner, O., Lowe, S. R., Sampson, L. & Galea, S. The geography of post-disaster mental health: spatial patterning of psychological vulnerability and resilience factors in New York City after Hurricane Sandy. *Int. J. Health Geogr.* **14**, 16 (2015).

90. Gruebner, O. et al. The geography of mental health and general wellness in Galveston Bay after Hurricane Ike: A spatial epidemiologic study with longitudinal data. *Disast. Medic. Public Health Prepared.* **10**, 261–273 (2016).

91. Lowe, S. R., Sampson, L., Gruebner, O. & Galea, S. Community unemployment and disaster-related stressors shape risk for posttraumatic stress in the longer-term aftermath of Hurricane Sandy. *J. Traum. Stress* **29**, 440–447 (2016).

92. Stokes, L. Electoral backlash against climate policy: A natural experiment on retrospective voting and local resistance to public policy. *Am. J. Polit. Sci.* **60**, 958–974 (2015).

93. Signoretta, P. E., Buffel, V. & Bracke, P. in *Climate Change and Health: Improving Resilience and Reducing Risks* (eds Leal Filho, W. et al.) 29–48 (Springer International Publishing, Cham, 2016).

94. Dunlap, R. E. & Jacques, P. J. Climate change denial books and conservative think tanks: Exploring the connection. *Am. Behav. Sci.* 57, (699–731 (2013).

95. Blakely, T. & Collings, S. Is there a causal association between suicide rates and the political leanings of government? *J. Epidemiol. Commun. Health* **56**, 722 (2002).

96. Jenkins, R. Making psychiatric epidemiology useful: The contribution of epidemiology to government policy. *Int. Rev. Psych.* **15**, 188–200 (2003).

97. Page, A., Morrell, S. L. & Taylor, R. J. Suicide and political regime in New South Wales and Australia during the 20th century. *J. Epidemiology Community Health* **56**, 766–772 (2002). **A surprising and fascinating empirical example of how the ideologies of governments can harm mental health in the most extreme way. The study has since been replicated in other settings.**

98. *2016 Canadian Index of Wellbeing National Report* (Univ. Waterloo, 2016).

99. Salvaris, M. Measuring the kind of Australia we want: The Australian National Development Index, the gross domestic product and the global movement to redefine progress. *Aus. Econ. Rev.* **46**, 78–91 (2013).

100. Hall, J., Giovannini, E., Morrone, A. & Ranuzzi, G. *A Framework to Measure the Progress of Societies* Working Paper No. 34 (OECD, 2010).

101. *Well-being of Future Generations (Wales) Act* (National Assembly for Wales, 2015).

102. Adger, W. N. Place, well-being, and fairness shape priorities for adaptation to climate change. *Glob. Environ. Change* **38**, A1–A3 (2016).

103. Lawrence, R. J & Gatzweiler, F. W. Wanted: A transdisciplinary knowledge domain for urban health. *J. Urban Health* **94**, 592–596 (2017).

104. Pearson, A., Jordan, Z. & Munn, Z. *Nursing Res. Pract.* http://doi.org/gb8br9 (2012).

105. Leiserson, C. E. & McVinney, C. Lifelong learning: Science professors need leadership training. *Nature* **523**, 279–281 (2015).

106. Dimkpa, D. Prevalence, causes and effects of academic corruption in Rivers State Universities, Nigeria. *Makerere J. Higher Educ.* **3**, 33–44 (2011).

107. Hesselmann, F., Graf, V., Schmidt, M. & Reinhart, M. The visibility of scientific misconduct: A review of the literature on retracted journal articles. *Curr. Sociol.* **65**, 814–845 (2016).

108. Ren, K. Fighting against academic corruption: A critique of recent policy developments in China. *Higher Educ. Policy* **25**, 19–38 (2012).

109. Abramo, G., D'Angelo, C. A. & Rosati, F. Career advancement and scientific performance in universities. *Scientometrics* **98**, 891–907 (2014).

110. Allesina, S. Measuring nepotism through shared last names: The case of Italian academia. *PLoS ONE* **6**, e21160 (2011).

111. Šebek, J. J. The power of kith and kin: Empirical evidence of kin among public administrators, judges and notaries in the Czech Republic. *Polit. Casopis* **23**, 23–43 (2016).

112. Frich, J. C., Brewster, A. L., Cherlin, E. J. & Bradley, E. H. Leadership development programs for physicians: A systematic review. *J. Gen. Intern. Med.* **30**, 656–674 (2015).

113. White, D. et al. Identifying potential academic leaders: Predictors of willingness to undertake leadership roles in an academic department of family medicine. *Can. Family Physic. 62* **109**, e102 (2016).

114. Detsky, A. S. How to be a good academic leader. *J. Gen. Intern. Med.* **26**, 88–90 (2011).

115. Maughan, D. & Berry, H. L. Mind games: Standing by while the world ignores climate change. *Brit. J. Psych. Int.* **12**, 29–30 (2015).

116. Arnold, R. D. & Wade, J. P. A definition of systems thinking: A systems approach. *Proc. Comp. Sci.* **44**, 669–678 (2015).

117. Kovats, R. S. et al. in *UK Climate Change Risk Assessment Evidence Report* Technical Ch. 5 (Adaptation Sub-Committee of the Committee on Climate Change, 2016).

118. Hajat, S. et al. in *Extreme Weather Events and Public Health Responses* (eds Kirch, W. et al.) 185–197 (Springer, New York, 2005).

119. Reacher, M. et al. Health impacts of flooding in Lewes: a comparison of reported gastrointestinal and other illness and mental health in flooded and non-flooded households. *Communic. Dis. Public Health* **7**, 39–46 (2004).

120. Tapsell, S. M., Tunstall, S. M. & Wilson, T. *Banbury and Kidlington Four Years After the Flood, An Examination of the Long-Term Health Effects of Flooding* (Flood Hazard Research Centre, Middlesex University, 2003).

121. Lock, S. et al. Secondary stressors and extreme events and disasters: A systematic review of primary research from 2010–2011. *PLoS Curr. Disast.* http://doi.org/cks4 (2012).

122. Waite, T. D. et al. The English national cohort study of flooding and health: Cross-sectional analysis of mental health outcomes at year one. *BMC Public Health* **17**, 129 (2017).

123. Munro, A. et al. Effect of evacuation and displacement on the association between flooding and mental health outcomes: A cross-sectional analysis of UK survey data. *Lancet Planet. Health* **1**, e134–141 (2017).

Author contributions

H.B. conceived, drafted and revised the manuscript. T.W. drafted Box 1 and formatted the manuscript. K.D. drafted 'required research and methods' sections. T.C. and V.M. included material about international projects. All authors critically reviewed the manuscript.

Additional information