Towards a Future Earth Health Research Agenda

Draft for discussion

Version 6: 22nd June 2017

Health Knowledge Action Network (KAN) Development Team

This paper draws on the overarching 2014 Future Earth Strategic Research Agenda which aims to address eight challenges to support the aspiration that by 2025 Future Earth will have inspired and created ground-breaking interdisciplinary science relevant to major global sustainability challenges.

The paper outlines potential priorities for health research that seeks to: protect and improve human health by elucidating, and finding effective responses to, the complex interactions amongst environmental change, pollution, pathogens, disease vectors, risk factors for non-communicable diseases, ecosystem services, and people's livelihoods, nutrition, mental health and well-being.

The purpose of this paper is to synthesize key research areas linking Global Environmental Change and human health that could form the basis of a research agenda, accepting that further elaboration depends on close involvement with potential users of new knowledge (global, national, sub-national) to identify policy and programmatic applications. The proposed agenda synthesizes critical topic areas identified through a series of scoping meetings and consultative discussions held by the Future Earth Health KAN Development Team[1]. The research topic areas are a starting point; they will be amended following feedback from additional consultations and further co-design with selected stakeholders.

This draft research agenda draws on the evolving evidence that many global environmental changes including climate change (and associated changes e.g. in extreme weather events, crop yields, air quality); land use change and biodiversity loss; ocean acidification; fresh water depletion; food system change; urbanization are affecting human health through a range of pathways. As numerous determinants shape health, and many environmental changes are co-occurring, cross-cutting research is necessary to address the intersections among the priority research areas identified in this draft agenda. For instance, patterns of urbanization and food systems actively affect each other (Seto and Ramankutty, 2016).

Research must lead to the development and evaluation of potential solutions that address health and environmental challenges in an integrated way. The Sustainable Development Goals. (SDGs) provide an overarching framework that addresses health specifically (SDG3) as well as the social, nutritional and environmental determinants of health (e.g. SDGs 1, 2, 4, 5, 6, 7, 11, 12, 13 etc.), requiring consideration of how policies in different domains can promote synergies in progress toward the SDGs. In alignment with Future Earth's overarching vision of progress toward global sustainability, multinational and transdisciplinary teams of researchers are pivotal to successful advancement of these pressing cross – cutting research topics.

[1] Bellagio Center meeting; online survey; side events (e.g. during the UN General Assembly, United National Environment Assembly, and a conference on "Avoiding Catastrophe – Linking Armed Conflict, Harm to Ecosystems and Public Health")

This draft research agenda seeks to identify the range of technologies, policies and actions that can help to promote adaptation and societal transformations to manage health risks of environmental change and reduce the environmental footprint of humanity.

Types of research questions:

For each research area, a broadly similar set of types of research questions can be identified:

1. What are the effects of observed environmental changes (including interactions between them) on human health and well-being and what are the causal pathways?
2. What are the likely health risks of the interactions of projected environmental changes with development choices? Which populations are most vulnerable, today and in the future to the range of health risks arising from environmental changes? (This implies a particular focus on low-income countries, together with poor populations in middle and high-income countries.)
3. How might health threats be prepared for, controlled or prevented, and health and well-being promoted through adaptation or mitigation policies (including the evaluation of iterative/adaptive management strategies)? What options *jointly* optimize factors such as health and well-being, equity, environmental sustainability, and sound economics? What are the limits to adaptation/resilience in preventing the adverse effects of environmental change?
4. How can trade–offs resulting from different policy options be identified and unintended adverse consequences of policies for health and wellbeing be minimized?
5. What are the economic implications of various policies, taking into account the effects on health? (That is, how can the costs of health effects be internalized?) Which approaches can foster sustainable and equitable prosperity whilst protecting natural systems.
6. What are the barriers to communicating and implementing research findings and how can appropriate evidence–based policies be implemented at scale? Which behavior change strategies can promote healthy and environmentally sustainable choices in different settings? Which insights from implementation research (including lessons learned, best practices, and guidance for scaling up) are pertinent to prospective decision-making? What are the social, political, societal levers and governance mechanisms that can enable the implementation of sustainable and health-supporting transformations?

Such research will require transdisciplinary approaches using a range of methods to study complex systems that link environmental change and human health, how they interact, and how they respond to different policy options and implementation strategies.

Research products:

We recommend that two major kinds of research products should be supported: systematic reviews and primary research, with approximately 15% of available funding allocated to the former and around 75% to the latter. Systematic reviews use explicit and standardized search strategies together with rigorous assessment of research quality to provide overviews of research findings relevant to specific research questions. They provide invaluable evidence to guide policy and identify research gaps. There are still very limited numbers of high quality systematic reviews relevant to global environmental change and health (Whitmee et al 2015).The remaining ~10 % of funding could be directed towards integration of

data collection to enable monitoring of risks and drivers, creating and synthesizing open access data sources for the research community, and policy outreach.

In general, research products should:

- Be policy-relevant, having been co-designed with stakeholders and decision-makers to assure maximum utility and impact.
- Address equity issues and economic impacts, explicitly considering public health and economic protection for the most vulnerable.
- Reflect partnerships between investigators in high, middle and low-income settings with special value placed on developing research capacity in middle and low-income settings.
- Consider implementation and evaluation of impact to encourage appropriate evidence-based policies.

Research themes:

Land use change, biodiversity loss and disease risk. Broad links between health and biodiversity have been identified (Keesing et al., 2010; Lovell et al., 2014; Bernstein, 2014; WHO-CBD 2015; Sandifer et al., 2015; Whitmee et al. 2015). In general, declining biodiversity is associated with increased disease risk. However, the association is complex and variable across settings, and mechanisms and pathways are often not fully understood. The health effects of specific species declines need to be better characterized and understood. Research could entail analysis of global datasets on biodiversity and health as well as primary studies of specific settings and populations. The evaluation of early warning systems and other approaches for more effective prevention and control of outbreaks are needed.

Unprecedented land conversion for intensive agriculture, deforestation, and extractive industries (e.g., mining, logging) has led to the spread of known infectious diseases and the emergence of novel pathogens (Loh et al. 2015). These, in turn, can cause significant morbidity and mortality resulting in billions of dollars of economic loss annually (Pike et al. 2014). However, despite clear linkages of land use change to increased rates of malaria, dengue, leptospirosis and Yellow Fever, the economic cost of these diseases has not been incorporated into ecosystem service models. Linking ecological, epidemiological and economic models to weigh the human health and ecosystem services costs (currently externalities) against the benefits of converting land can directly inform policy on when, where and how to convert or protect land. While infectious diseases are the best studied human health outcomes in this context, other outcomes, such as mental health and non-communicable disease (NCD) risk, have rarely been assessed and could be usefully included in future research. For example landscape fires are estimated to be responsible for about 300,000 fine particulate air pollution deaths per annum (by increasing risk of heart disease and other NCDs) (Johnston et al 2012). They also result in substantial greenhouse gas emissions and contribute significantly to biodiversity loss; research can inform strategies to minimize their impact and restore landscapes. Climate change can accelerate biodiversity loss and also lead to changes in the distribution and incidence of a range of infectious diseases including vector – borne, food and water-related diseases. Better understanding of the relative importance of different environmental drivers and their interactions is essential to inform more effective disease control strategies.

There is also a need further research to improve understanding of the pathways and mechanisms by which exposure to nature can influence health outcomes (mental and physical), including possible dose

response effects (Shanahan et al 2016). Nature conservation can result in health benefits through a range of mechanisms e.g. through reduced air pollution, clean water, reduced vector borne disease risk and improving mood but the putative benefits need better quantification in a range of settings.

Food systems and nutrition. Feeding the world's population remains a pressing challenge (Godfray et al., 2010). Human populations are growing, while globalization is spurring on a nutrition transition in low- and middle-income countries to diets high in fat and sugar, with major effects on global health particularly by increasing the risks of NCDs Hawkes et al., 2006). The growing demand for food, in particular for animal-based products, are placing pressure on the world's food systems and on the ecosystems that support them. For example, food production is driving the conversion of forests to farmland, straining freshwater supplies, depleting fish stocks, accounting for substantial greenhouse gas emissions, reducing biodiversity and increasing the use of chemical inputs to agriculture (Tilman & Clark, 2014). Additionally, climate change will have important impacts on agricultural productivity, with the most negative effects in tropical and sub-tropical regions (Liu et al., 2013; Hertel 2016). There are important health implications, both directly via nutritional pathways, such as increased risks of stunting (Lloyd, Chalabi, Kovats 2011), and indirectly for example by increasing the impoverishment of subsistence farmers. Increasing exposure to heat stress as a result of climate change will also threaten the livelihood of subsistence farmers and other outdoor workers in sub-tropical and tropical regions (Kjellstrom, Holmer, Lemke 2009).

Other environmental trends, such as declines in pollinators, can increase the risks of nutrition-related non –communicable and communicable diseases (Smith et al 2015) and the effectiveness of policies to halt and reverse such declines need assessing. Understanding the simultaneous effects of multiple interacting social and environmental changes on nutrition and health is a key priority. Research could entail analyzing environmental and health consequences of the current and projected agri-food systems (e.g. under different scenarios of climate change, water, chemical, or waste management or changing agricultural technologies and trade);developing innovative foods or production methods that optimize both health and environment outcomes; identifying and evaluating dietary changes that are culturally acceptable, economically feasible, healthy, and environmentally sustainable (Hallström et al., 2015; Aleksandrowicz et al., 2016, Milner et al 2017);and assessing combinations of strategies. A particular emphasis on research to address the vulnerability of subsistence agriculture to climate and other environmental stressors is needed. Results should be relevant to decision makers in agriculture, nutrition, and development aid sectors.

Urbanization and health. The majority of the global human population now lives in urban centers. Cities are responsible for 85% of global economic activities and about 75% of greenhouse gas emissions. The effects of urban living on health and wellbeing vary widely, and are affected by wealth, social status, and specific features of the urban environment (WHO, 2016). In high and middle-income countries, urban health threats include air pollution, noise, barriers to physical activity, absence of green space, and in some cases social exclusion and poverty. Cities in low income countries confront all these problems, compounded by critical shortages of infrastructure (potable water, sanitation, electricity, waste management, transport), uncertain land tenure, poor governance, and other challenges (Eckert and Kohler, 2014; Rao & Peters, 2015; Li et al., 2016; Oni et al., 2016). Cities are subject to the urban heat island effect, which will intensify with climate change (Koomen & Diogo, 2017) and the built environment will be an important mediating factor – for example green space can reduce the health

island effect and passive and active cooling of buildings may reduce the health effects of heat extremes. More research is needed to determine cost effective adaptation in different settings.

Many cities are susceptible to sudden disruptions, for reasons ranging from coastal locations subject to storm surges and sea level rise to precarious infrastructures; an important priority is understanding these vulnerabilities and building resilience. There is considerable research and practice underway that relates to many of these dimensions of urban health, some focused primarily on urban sustainability or resilience, and some focused directly on health. Examples include work undertaken through ICSU's initiative on Health and Wellbeing in the Changing Urban Environment and networks such as ICLEI, C40, and the Rockefeller Foundation supported 100 Resilient Cities. Future Earth Health can build on this work, utilizing complex systems approaches and innovative tools such as in situ sensors and smartphone-based geocoded personal data collection.

Sustainable transport systems, including efficient low emission public transport networks and the promotion of active travel (walking and cycling) have great potential to improve health through reduced air pollution, reduced vehicular crashes, and increased physical activity. Results will be useful to urban political leaders, urban planners, civil society, public health professionals, developers and builders, and many others. In summary, research is needed to identify health-promoting, cost-effective design features of the city, to optimize health, environmental and economic benefits, to promote resiliency, to reduce environmental footprints and to identify effective implementation and governance strategies.

Energy, health, climate change, and air quality. Energy use supports many of life's necessities - food production and preparation, home heating, transportation, manufacturing, and more. However, the energy strategy that has brought us to the Anthropocene - massive combustion of fossil fuels - has created a host of negative health, environmental, and other outcomes (Smith et al., 2012; 2013). Meanwhile, in low- and middle-income countries, many people lack sufficient energy, and available energy sources such as biomass (particularly when burned indoors in close quarters) bring many ill effects (Wilkinson et al., 2007). Among the most obvious of these ill effects is air pollution, both indoor and ambient, which accounts for substantial mortality (about 7 million deaths annually) and morbidity globally. Eighty five per cent of fine particulate air pollution is related to energy use (International Energy Agency, 2016). Innovative energy strategies and technologies offer promise for health, equity, and sustainable development (Buonocore et al., 2016; Rosenthal et al., 2017); well-crafted policies can reduce GHG and short lived climate pollutant emissions whilst yielding co-benefits across multiple domains, including health (Haines et al, 2009;Smith et al, 2009). Research at the interface of energy, health, air quality, and climate change could help document the health and socio-economic effects of energy sources including biomass, manufactured biofuels, fossil fuels, and renewables; document the health effects of emerging technologies such as hydraulic fracturing; and analyze the health, socio-economic and environmental effects of strategies to promote clean renewable energy sources. Additionally, detailed scenario modelling for future health risks from a range of climate change projections resulting from different energy choices is warranted, e.g. building on Shared Socioeconomic Pathways (SSPs) (O'Neill et al 2014) to strengthen the representation of health. Results will help inform energy policy decisions in high, middle and low-income country settings.

Disasters and extreme weather and climate events: vulnerability, preparedness, and response. Global change is increasing the risks of a range of disasters at local to regional scales - some rapid and "kinetic"

such as intense storms and floods; others such as heat waves and landscape fires; and still others, which may persist over months and even multiple years, such as droughts and pandemics. Disasters cause acute injuries and deaths, and follow-on impacts, including infectious diseases, mental illness, hunger, conflict, and population migration, can be severe (CRED, 2015). Often these effects are complex and inter-related, as in the outbreak of cholera in East Africa throughout the 2015-2016 El Niño. Research could help advance the science of disaster (impact based) event forecasting, the understanding of disaster impacts on disease dynamics, mental health, food systems, etc. as well as the practice of disaster preparedness and response, and the promotion of disaster resilience. This work could include evaluating the effectiveness of ecosystem-based strategies such as the protection of wetlands, coral reefs and mangroves and the effectiveness of social safety nets, and preparedness efforts, particularly in urban contexts. Climate change is expected to accentuate vulnerability to a wide range of extreme weather and climate related disasters, and increase population exposure to harm in the future. Future modeling and scenarios of future health risks, potential losses and damages to critical health infrastructure, including economic and societal costs of disaster preparedness and response is warranted using SSPs (see above). Such research could also contribute to our understanding of the limits to adaptation beyond which there are threats to habitability of specific locations, as a result for example of exposure to extreme heat stress or sea level rise in low lying regions. Research into reducing vulnerability and enhancing resilience should cut across several domains, including (but not limited to) the built environment, natural ecosystems, social and cultural contexts, economics, and governance. This approach can be implemented in existing multi-hazard frameworks (e.g. Sendai Framework for Disaster Risk Reduction) to inform disaster impacts prediction efforts and prevention parameters. Research outputs can be used by local authorities, disaster management and line ministries, private sector, NGOs and other civil society partners involved in vulnerability reduction and resilience building efforts. In particular, vulnerability considerations should identify and address gender, socio-economic status, and other determinants of health that may contribute to inequity.

Health in the Circular economy. Current patterns of economic development are inherently inefficient and produce large amounts of waste including pollutants affecting human health. Much more efficient use of natural resources and energy together with more effective regulation of the use and disposal of potentially toxic chemicals can result in substantial benefits to health and natural systems. However, the effects of the dispersion of many chemicals in the environment leading to widespread population exposure are still poorly understood including endocrine disruptors, neurotoxicants and pharmaceuticals. Increasingly electronic and other waste is exported to low income countries where regulations are lax and many millions of people worldwide work in or live in close proximity to waste dumps (Lancet Commission on Pollution 2017 forthcoming). Freshwater supplies are being depleted for irrigation and other purposes in many parts of the world with serious implications for future food production and the economy. Contamination of freshwater with arsenic, saline, agricultural runoff and industrial chemicals is a serious threat to health in some parts of the world. Better quantification of exposure and health effects of toxic chemicals including their indirect effects through ecosystems is needed (CBD/WHO State of Knowledge report 2015). The circular economy aims to promote greater resource productivity to reduce waste and avoid pollution including through reuse, recycling and increased durability of products. Whilst there has been exploration of the economic incentives and promising technologies that would support a circular economy (e.g. EU action plan for the Circular

Economy), little is known about the implications for health. Health benefits could accrue from reduced exposure to toxic pollutants including through waste water recycling and reduced occupational exposures but there are also risks to health for example from poorly regulated recycling and trade in waste products. Health impact assessment should be integrated into evaluations of technologies and policies to support progress towards the circular economy.

Supporting research and monitoring of GEC and Health.

The Anthropocene has put unprecedented pressure on natural systems, our landscapes and our climate, with profound implications for health. However, there is no current mechanism to monitor planetary health on a global scale. National and regional networks have been set up to monitor different aspects of planetary health. For example, the community-based INDEPTH Network conducts comprehensive health and epidemiological surveillance in Africa and Asia, with links to local health care systems and universities. Global Disease Detection sites managed by the US CDC evaluate health risks among similarly-selected cohorts in a range of countries. The USAID-Emerging Pandemic Threats Predict project measures emerging zoonotic disease risk in around 30 countries. Other monitoring sites provide detailed data on biodiversity (e.g. Group on Earth Observations Biodiversity Observation Network, GEO-BON), disasters (the Emergency Events Database, or EM-DAT, at the Université Catholique de Louvain Centre for Research on the Epidemiology of Disasters, and the Global Risk Model and Disaster Information Management System "DesInventar"), climate, land use change and other environmental and societal indicators. The Lancet Climate Countdown process aims to monitor the effects of climate change on health, the effectiveness of adaptation strategies, health co-benefits of mitigation policies and other relevant indicators. However many other environmental changes affect health and thus a more comprehensive approach is needed to provide a broad view of the many components that may contribute to health and assess possible co-benefits and trade-offs (for example, how a given scenario could affect management of water resources, levels of air pollution, GHG emissions, exposure to toxic chemicals and drive health outcomes).

The Future Earth Health KAN could play a critical role in 1) development of integrated health metrics, indicators and tools, and 2) assessment of effective ways to integrate these different monitoring platforms to provide the first dedicated monitoring network, which provides publicly accessible data on progress on the protection of natural systems and human health, 3) pioneering how to incorporate data from integrated monitoring systems into future projections of the effects of climate and other environmental changes on health outcomes.

Systematic reviews have profoundly influenced the practice of clinical medicine by ensuring that policy and practice recommendations are based on the best available evidence, minimizing bias and providing rigorous estimates of effect size of different interventions. The Cochrane Collaboration includes 37,000 contributors from more than 130 countries – who 'work together to produce credible, accessible health information that is free from commercial sponsorship and other conflicts of interest '. Smaller initiatives such as Environmental Evidence have started to apply systematic review approaches to environmental issues, yet many more systematic reviews are needed. There is a need to adapt the methods used for systematic reviews in the clinical domain to reflect the complexity of relationships between environmental change and health and the range of effects of policies to promote health and sustainability. Research funders

should support collaborative efforts to undertake systematic reviews and develop appropriate methods relevant to planetary health.

Conclusions

Health is a cross cutting theme within the Future Earth agenda, influenced by many socioeconomic and environmental factors. Protecting and improving health are a priorities for policymakers in a range of countries and better quantification of the health effects of policies to adapt to or mitigate environmental change can help motivate transformative change towards a more sustainable economy.

References:

Aleksandrowicz L, Green R, Joy EJ, Smith P, Haines A. 2016. The impacts of dietary change on greenhouse gas emissions, land use, water use, and health: A systematic review. *PLoS One*11:e0165797.

Bernstein AS. 2014. Biological diversity and public health. *Annu Rev Public Health* 35:153-167.

Buonocore JJ, Luckow P, Norris G, Spengler JD, Biewald B, Fisher J, et al. 2016. Health and climate benefits of different energy-efficiency and renewable energy choices. *Nature Clim Change* 6:100-105.

Castleden M, McKee M, Murray V, Leonardi G. 2011. Resilience thinking in health protection. *J Public Health (Oxf)* 33:369-377.

Convention on Biological Diversity and World Health Organization. 2015. *Connecting Global Priorities: Biodiversity and Human Health.* Montreal: CBD and WHO.

CRED (Centre for Research on the Epidemiology of Disasters). 2015. *The Human Cost of Natural Disasters: A Global Perspective*. Brussels: CRED.

Eckert S, Kohler S. 2014. Urbanization and health in developing countries: A systematic review. *World Health & Population* 15:7-20.

Godfray HC, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, et al. 2010. Food security: The challenge of feeding 9 billion people. *Science* 327:812-818.

Haines A, McMichael AJ, Smith KR, Roberts I, Woodcock J et al .Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers. Lancet 2009; 374: 2104-14

Hallström E, Carlsson-Kanyama A, Börjesson P. 2015. Environmental impact of dietary change: A systematic review. *J Cleaner Production* 91:1-11

Hawkes, C., 2006. Uneven dietary development: linking the policies and processes of globalization with the nutrition transition, obesity and diet-related chronic diseases. *Globalization and health*, 2(1), p.4.

Hertel TW. 2016. Food security under climate change. *Nature Clim Change* 6:10-13.

International Energy Agency. World Energy Outlook Special report IEA Paris France 2016

Johnston, F. H., Henderson, S. B. et al. 2012. Estimated global mortality attributable to smoke from landscape fires. Environmental Health Perspectives. 120(5); 695-701. DOI: 10.1289/ehp.1104422

Keesing F, Belden LK, Daszak P, Dobson A, Harvell CD, Holt RD, et al. 2010. Impacts of biodiversity on the emergence and transmission of infectious diseases. *Nature* 468:647-652.

KjellstromT, Holmer I, Lemke B. (2009) Workplace heat stress, health and productivity – an increasing challenge for low and middle income countries during climate change. Global Health Action 2009(on website: www.globalhealthaction.net). DOI 10.3402/gha.v210.2047.

Koomen E, Diogo V. 2017. Assessing potential future urban heat island patterns following climate scenarios, socio-economic developments and spatial planning strategies. *MitigAdaptStrategGlob Change* 22:287-306.

Li X, Song J, Lin T, Dixon J, Zhang G, Ye H. 2016. Urbanization and health in China, thinking at the national, local and individual levels. *Environ Health* 15:113-123.

Liu J, Folberth C, Yang H, Rockstrom J, Abbaspour K, Zehnder AJ. 2013. A global and spatially explicit assessment of climate change impacts on crop production and consumptive water use. *PLoS One*8:e57750.

Lloyd SJ, Kovats RS, Chalabi Z Climate change, crop yields, and undernutrition: development of a model to quantify the impact of climate scenarios on child undernutrition**.** Environ Health Perspect. 2011 Dec;119(12):1817-23. doi: 10.1289/ehp.1003311. Epub 2011 Aug 15.

Loh EH, Zambrana-Torrelio C, Olival KJ, Bogich TL, Johnson CK, Mazet JA, Daszak, P et al. 2015. Targeting transmission pathways for emerging zoonotic disease surveillance and control. *Vector Borne & Zoonotic Dis* 15:432-437.

Lovell R, Wheeler BW, Higgins SL, Irvine KN, Depledge MH. 2014. A systematic review of the health and well-being benefits of biodiverse environments. *J Toxicol Environ Health Part B, Crit Rev* 17:1-20.

Milner J, Joy EJM, Green R, Harris F, Aleksandrowicz L, Agrawal S, Haines A, Dangour A Projected health effects of realistic dietary changes to address freshwater constraints in India: a modelling study Lancet Planetary Health 1, 2017 http://www.thelancet.com/pdfs/journals/lanplh/PIIS2542-5196(17)30001-3.pdf

O'Neill, B.C., Kriegler, E., Riahi, K. et al. A new scenario framework for climate change research: the concept of shared socioeconomic pathways Climatic Change (2014) 122: 387. doi:10.1007/s10584-013-0905-2

Oni T, Smit W, Matzopoulos R, Hunter Adams J, Pentecost M, Rother H-A, et al. 2016. Urban health research in africa: Themes and priority research questions. *J Urban Health* 93:722-730.

Pike J, Bogich TL, Elwood S, Finnoff DC, Daszak P (2014) Economic optimization of a global stategy to reduce the pandemic threat. Proceedings of the National Academy of Sciences, USA 111:18519-18523

Rao KD, Peters DH. 2015. Urban health in India: Many challenges, few solutions. *The Lancet GlobalHealth*3:e729-e730.

Rosenthal J, Balakrishnan K, Bruce N, Chambers D, Graham J, Jack D, et al. 2017. Implementation science to accelerate clean cooking for public health. *Environ Health Persp*125:A3-a7.

Sandifer PA, Sutton-Grier AE, Ward BP. 2015. Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Ecosystem Services* 12:1-15.

Seto KC, Ramankutty N. 2016. Hidden linkages between urbanization and food systems. *Science* 352:943-945.

Shanahan D et al Health Benefits from Nature Experiences Depend on Dose. *Scientific Reports* **6**, : 28551 (2016)doi:10.1038/srep28551

Smith KR, Jerrett M, Anderson HR, Burnett RT, Stone V, et al. 2009. Public health benefits of strategiesto reduce greenhouse-gas emissions: health implications of short-lived greenhouse pollutants. *Lancet*374:2091–2103.

Smith KR, Balakrishnan K, Butler C, Chafe Z, Fairlie I, Kinney P, et al. 2012. Energy and health. In: *Global Energy Assessment: Toward a Sustainable Future*, Global Energy Assessment Writing Team, Ed. Cambridge, U.K.:Cambridge University Press and the International Institute for Applied Systems Analysis.

Smith KR, Frumkin H, Balakrishnan K, Butler CD, Chafe ZA, Fairlie I, et al. 2013. Energy and human health. *Annu Rev Public Health* 34:159-188.

Smith, MR, Singh G , Mozzafarian D, Myers S et al. Effects of decreases of animal pollinators on human nutrition and global health: a modelling analysis Lancet , 2015 386, 1964 – 1972

Tilman D, Clark M. 2014. Global diets link environmental sustainability and human health. *Nature* 515:518-522.

Whitmee, S., A. Haines, C. Beyrer, F. Boltz, and A. G. Capon. 2015. "Safeguarding Human Health in the Anthropocene Epoch: Report of The Rockefeller Foundation–Lancet Commission on Planetary Health." *The Lancet*. thelancet.com. http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)60901-1/fulltext?nr_email_referer=1)

WHO. 2016. *Health as the pulse of the new urban agenda*. In: United Nations Conference on Housing and Sustainable Urban Development. Quito:World Health Organization.

Wilkinson P, Smith KR, Joffe M, Haines A. 2007. A global perspective on energy: Health effects and injustices. *Lancet* 370:965-978.