Chapter 20
Sustainability and Health

Maud M.T.E. Huynen and Pim Martens

Abstract Achieving good health should be an integral part of the current discussions about sustainable development. It is increasingly recognized that health research (and policy) requires a systems approach and the past decades have witnessed an emerging recognition of the multidimensional and multilevel causation of population health. An ever growing number of health researchers argue that the health of a population can – or must – be viewed within the broader system of health determinants. Consequently, in our effort to assess the health impacts of global (environmental) change, we have to be aware of the limitations of the traditional reductionist approach.

Stressing the need for a system-based approach toward health, this chapter discusses and illustrates a conceptual model describing the broader context and multicausality of our health. We apply this framework to a widely discussed health impact of climate change, namely, the emergence of malaria in the African highlands. This clearly demonstrates that malaria in East Africa's highlands presents an interesting case study for understanding the importance of the system's interactions between climate and non-climate factors in shaping human vulnerability to the adverse health impacts of global warming. Climate change is believed to primarily affect the intrinsic malaria transmission potential, but this relationship interacts with other factors and developments that affect disease dynamics as well.

However, trying to conceptually describe the system involved is only one of the first steps in applying a system-based approach toward health. Hence, we briefly elaborate on some example tools from the sustainability science toolkit (modeling, scenario analyses, and participatory methods) that are available and conceivable in order to advance further systems research in the field of health and sustainable development. The chapter concludes with a discussion of possible barriers to adopting a sustainability science approach toward health, in an effort to explain the slow progress made so far.

Keywords Climate change • Health • Highland malaria • System-based approach • Sustainability science

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1 Introduction

Achieving good health has become an accepted international goal, and our (future) health should be an integral part of the current discussions about sustainable development. The Brundtland Commission (Brundtland 1987) argued that "the satisfaction of human needs and aspirations is the major objective of development" and "sustainable development requires meeting the basic needs of all and extending to all the opportunity to satisfy their aspirations for a better life." There have been several attempts to identify what our basic needs actually encompass. Well-known theories are, for example, the ones developed by Maslow (1954, 1968) and Max-Neef (1991), and in both approaches maintaining or improving our physical (and mental) health is seen as a crucial element.

The relationship between sustainable development and population health works two ways. As the world around us is becoming progressively interconnected and complex, human health is increasingly perceived as the integrated outcome of its ecological, social-cultural, economic, and institutional determinants. Due to its multidimensional causality, good health is often seen as an outcome of sustainable development. McMichael (2006; McMichael et al. 2000) argues that health can be seen as an important high-level integrating index that reflects the state – and, in the long term, the sustainability – of our natural and socioeconomic environment. The increasing widespread and long-term risks to population health are, therefore, at the heart of non-sustainability. Wilcox and Colwell (2005), for example, agree that no issue could be a more fundamental measure of sustainability than public health. The other way around, however, a healthy population is also necessary to achieve sustainable development. As Brundtland (2002), Director-General Emeritus of the World Health Organization (WHO), puts it: "a healthy life is an outcome of sustainable development, as well as a powerful and undervalued means of achieving it." The WHO Commission on Macroeconomics and Health (2001), for example, concluded that good health is a central input to poverty reduction and socioeconomic development.

The past decades have witnessed a growing recognition of the multidimensional and multilevel causation of population health. An ever growing number of health researchers (Wilcox and Colwell 2005; Pearce and Merletti 2006; Albrecht et al. 1998; Colwell 2004; McMichael 2005) argue that the health of a population can – or must – be viewed within the broader system of health determinants. Populations are not simply the collection of individuals, but are shaped by, and shape, the systematic context in which they operate (Pearce and Merletti 2006). Risk factors for disease do not operate in isolation but occur in a particular population context. Upstream forces play an important role in global health research (Sreenivasan and Benatar 2006). These upstream or *contextual factors* may have large impacts, but their effects are nonlinear and less predictable (Philippe and Mansi 1998). As our attention moves upstream in the causal chain of health determinants, there is an increasing interest in multilevel – and systems – approaches (Pearce and Merletti 2006; McMichael 1995, 1999; Pearce 2004). Various terms have been used to describe such broader approaches to population health, such as eco-epidemiology (Martens 1998; Susser and Susser 1996; Ladd and Soskolne 2008; Soskolne and Broemling 2002), ecological perspective on health (McLaren and Hawe 2005), social-ecological systems perspective on health (McMichael 1999), ecosystem approach to public health (Arya et al. 2009), ecological public health (Morris 2010), and bio-complexity approach to health (Wilcox and Colwell 2005; Colwell 2004). As Soskolne et al. (2007) state, we "must embrace greater complexity" as "the traditionally used, reductionist, linear approaches are inferior for understanding the interactive webs that are critical for sustainable development and for the health and well-being of future generations." Similarly, the WHO argues that systems thinking works to reveal the underlying characteristics and relationships of systems (de Savigny and Adam 2009).

Stressing the need for a *system-based approach toward health*, this chapter first discusses a conceptual model describing the multi-causality within the health system. This will be further illustrated by a description of the climate and non-climate drivers behind the observed emergence of malaria in the African highlands. Accordingly, we will briefly elaborate on some example tools from the sustainability science toolkit that are available and conceivable in order to advance further systems research in the field of health and sustainable development. Finally, the chapter concludes with a discussion of possible barriers to adopting a sustainability science approach toward health, in an effort to explain the slow progress made so far.

Q: Reflect on the notion that "health is an integrated index of how sustainable we are managing our natural, social, and economic resources."

2 A Systems Approach Toward Population Health

In order to illustrate the broader context and multi-causality of our health, Huynen et al. (2005; Huynen 2008) developed a *conceptual framework for population health* (Fig. 20.1). Their model combines the nature of health determinants and their level of causality into a basic framework that conceptualizes *the multi-causality of population health*.

In order to differentiate between determinants of a different nature, the customary distinction between institutional, sociocultural, economic, and environmental determinants is made. These determinants operate at different hierarchical levels of causality. The chain of events leading to a specific health outcome includes both proximal and distal causes—proximal factors act directly to cause disease or health gains, while distal determinants are set further back in the causal chain and act via intermediate causes. In addition, contextual determinants play an important role. These can be seen as the upstream macro-level conditions shaping the distal and proximate health determinants; they form the context within which the distal and proximate factors operate and develop. Determinants with different positions in the

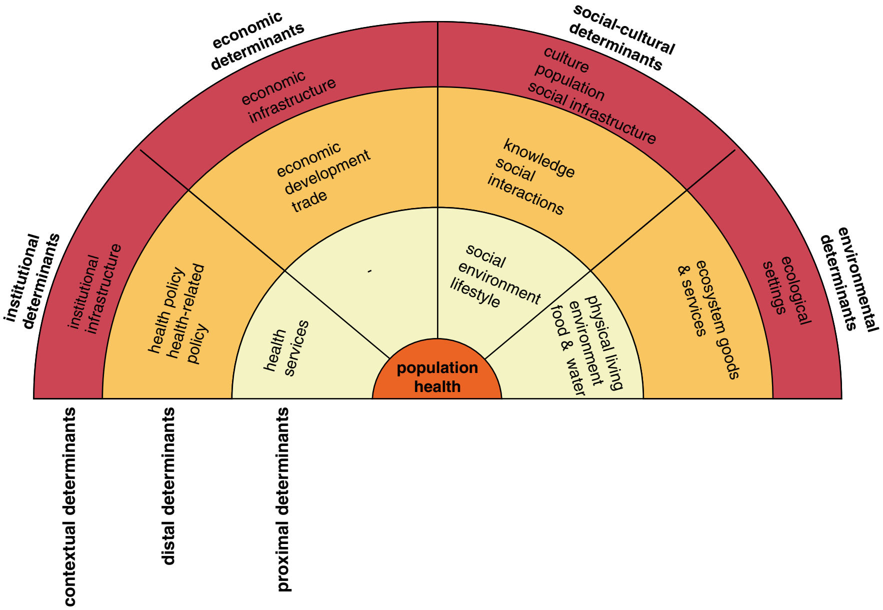

Fig. 20.1 Multi-nature and multi-level framework for population health, developed by Huynen et al. (2005)

causal chain probably also differ in their temporal dimensions. Individual-level proximal health risks can be altered relatively quickly, for example, by a change in personal behavior; for disease rates in whole populations to change requires slower and more structural changes in contextual factors, often over the course of a few decades (Huynen 2008).

Figure 20.1 shows the wide-ranging overview of the health determinants that can fit within this framework. The way different factors and developments within the system interact is critical to how the whole system works and, subsequently, how vulnerable populations are to a particular health risk.

A key example of a global health challenge to sustainable development is the health impact of climate change, and one of the first steps in applying a system-based approach toward climate change and health entails describing the system involved. Box 20.1 discusses the climate and non-climate drivers behind a well-recognized health impact of climate change, namely, the emergence of highland malaria in the East African highland. Accordingly, Table 20.1 applies the above framework (in Fig. 20.1) to this case study.

Box 20.1 and Table 20.1 clearly demonstrate that malaria in East Africa's highlands presents an interesting case study for understanding the importance of the interactions between climate and non-climate factors in shaping human vulnerability to the adverse health impacts of global warming (Huynen et al. 2013). A 2011 report by the Africa Initiative (Tesi 2011) also stressed the multi-causality of malaria; although climate change has been associated with the observed malaria

Box 20.1: Case Study—The Emergence of Highland Malaria in the East African Highland (Based on Huynen et al. 2013)

Climate (change) is believed to be an important factor in the dynamics of malaria transmission (Martens et al. 1999; Chaves and Koenraadt 2010; IPCC 2007, 2014). Temperature affects mosquito survival as well as parasite development. Additionally, mosquito survival is also affected by changes in humidity, while developments in rainfall (patterns) can affect the number of suitable breeding sites. As a result, the past two decades have witnessed considerable debate about the importance of climate change in driving the observed changes in malaria distribution and transmission in highland regions. A review study by Chaves and Koenraadt (2010) concluded that the linkage between climate change and malaria in the highlands of Africa is rather robust. The same publication stressed, however, that overemphasizing the role of climate as the autonomous main driver of highland malaria does not account for the clear multifactorial causality of disease transmission (Chaves and Koenraadt 2010).

In an elaborate literature review, Cohen et al. (2012) identified the following suggested causes of past malaria resurgence events: weakening of control activities (e.g., due to funding constraints, poor execution, purposeful cessation), technical problems (e.g., vector resistance, drug resistance), human or mosquito movement, development/industry changes (including land use change), socioeconomic weakening, climate/weather, and war. Malaria is also closely linked to poverty; poorer communities have a higher disease risk due to, for example, lower (financial) access to health services, poorer nutritional status, lower education levels, poor sanitation, and inadequate housing (Ricci 2012). Although the above listing is probably far from exhaustive, it clearly illustrates that climate change is just one of many processes that affect infectious disease risk (Morse 1995; Cohen 2000; Sutherst 2004; McMichael 2004; IPCC 2014. Hence, the assessment of climate change impacts on malaria is challenged by the complex interactions between climate and non-climate factors. We will explore this in more detail by looking at the various drivers of malaria emergence in the East African highlands.

The highlands are a fragile ecosystem under great pressure from increasing populations, deforestation, and increased farming (McMichael 2003). East African highlands are one of the most populated regions in Africa, and their population growth rates are among the highest in the world. As a result, the regions are also faced with high rates of poverty. Poverty and demographic pressures have spurred massive land use and land cover changes (including massive deforestation) for agricultural practices (Himeidan and Kweka 2012). The upland communities are often remote from regional health centers, and health services are patchy making the surveillance and control of malaria difficult. It is increasingly acknowledged that the risk of highland malaria moving to higher altitudes depends on the interplay between climate change and, for example, land use change, population growth, population movement,

(continued)

Box 20.1: (continued)
agricultural practice (e.g., pesticide use, irrigation systems), cessation of malaria control activities, drug resistance, and socioeconomic status.

Malaria invasion of the African highlands has been associated with the migration of people from the lower areas to the higher altitudes (Lindsay and Martens 1998), introducing the malaria parasite into highland regions. The limited immunity of people living at higher altitudes could have played a role. Furthermore, the massive deforestation in East Africa has shown to be associated with changes in the local climate. As such, both the land use changes and global warming may act together in causing the observed regional change in the local climate of the East African highlands (Himeidan and Kweka 2012). Changes in crop choice can also play a role, as demonstrated by the invasion of malaria in the Bure highlands of Ethiopia due to the fact that the mosquito vector thrived on feeding on maize pollen, just shortly after this crop was introduced (Ye-Ebiyo et al. 2000; Kebede et al. 2005). Irrigation activities and forest clearing have been associated with increases in vector densities due to, for example, enhancing mosquito breeding sites (Himeidan and Kweka 2012). Susceptibility to the increasing mosquito densities and associated malaria risk is further complicated by the high poverty rates in the East Africa highlands. Fortunately, the highlands have experienced a reduction in malaria prevalence since the early 2000s, due to ongoing malaria interventions (Chaves and Koenraadt 2010; Himeidan and Kweka 2012; Stern et al. 2011). However, the sustainability of these interventions may be questioned (Himeidan and Kweka 2012). African countries mostly rely on external donors, and global funding levels for malaria are in an increasingly precarious state (Pigott et al. 2012); weakening of malaria control programs has been an important driver of observed past causes of malaria resurgence (Cohen et al. 2012). Recently, Artzy-Randrup et al. (2010) hypothesized that the influence of climate change on malaria also interacts with the spread of drug resistance through altered levels of transmission intensity.

invasion in African highlands, other factors are involved as well in accelerating this process. The report argues that climatic factors (increases in temperature, rainfall, and humidity) act as primary factors, because as long as the disease transmission is constrained by climatic factors, the disease will automatically be limited as well. The secondary factors, such as drug resistance, agricultural development, population growth, migration, conflicts, and land use change, can accelerate this process put in motion by climatic factors. Similarly, Chaves and Koenraadt (2010) emphasize that “a multidimensional array of underlying factors is likely to be at play here, most of which may be sensitive to climatic change.” Hence, although climate change is believed to primarily affect the intrinsic malaria transmission potential (Cohen et al. 2012; Tesi 2011), it interacts with other factors and developments that affect disease dynamics as well. Most of them are expected to be affected by climate

Table 20.1 The emergence of highland malaria in Africa: example system variables

Causal level of health determination	Institutional	Economic	Sociocultural	Environmental
Contextual	Public health infrastructure, including a number of health-care centers in highland areas	Economic infrastructure	High population growth and density resulting in demographic pressures	Climate change, ecosystem change
Distal	Health policy including efforts to reduce malaria, agricultural policies	Slow economic development, agricultural sector developments	Population movement, high poverty rates	Substantial land use/cover change, agricultural irrigation, altered local climate regulation
Proximal	Pre-2000: lack of (access to) health care and control/surveillance activities Post-2000: increasing malaria interventions and control	–	Lack of immunity to malaria in highlands, wrong use of antibiotics or bed nets, drug resistance	Changes in local climate including temperature rise, increase in mosquito breeding sites

change, such as agriculture, food security, migration, and poverty (IPCC 2007; McMichael et al. 2012). Hence, it is increasingly recognized that research and policy in the field of climate change and health requires a systems approach (Huynen et al. 2013), building on insights from sustainability science.

Q: In what world regions will vector-borne disease, like malaria, be most sensitive to climatic changes?

3 Adopting a Systems Approach to Health: Sustainability Science Tools

The idea that problem framing using conceptual models may be used to address complex (policy) challenges is not new (Morris 2010), and the previous section has put the infectious disease risks associated with climate change within a broader systems context. Although problem framing in order to wrap your head around all relevant variables within the climate-health system is an important step forward, it might represent only the tip of the iceberg. Within this system there are dynamic processes and feedback loops, resulting in emergent system properties (i.e., sum more than its parts), points of bifurcation, and possible tipping points.

So how must we address such a broad issue, encompassing debated relationships between multiple interacting factors operating at different positions in the causal chain? Building on insights from Mode-2 science (Gibbons et al. 1994), post-normal science (Ravetz 1999; Funtowicz and Ravetz 1993, 1994), and sustainability science (Kates et al. 2001; Martens 2006), a systems approach toward health should account for a number of shared research principles such as transdisciplinarity, participation of nonscientific stakeholders, co-production of knowledge, recognition of uncertainty and system's complexity, and the quest for an exploratory science instead of a predictive one. This challenges epidemiologists, as well as scientists and practitioners in other relevant disciplines, to extend their conventional methodological boundaries. To date, however, an unprecedented gap is apparent between paradigm and practice. Yet innovative methods and tools are emerging in other fields, providing examples of those available and conceivable in order to advance further systems research in the field of health and sustainable development (Soskolne et al. 2009):

– *Modeling the health system*: In modeling population health, traditional epidemiological approaches usually use regression techniques to explore the relations between health determinants and health outcomes (Soskolne et al. 2009; Galea et al. 2010). However, these usually provide only limited insight into the dynamics behind changing health patterns; the fundamental limitation of these statistical techniques in addressing interacting, dynamic, discontinuous, or changing relationships within the system remains (Galea et al. 2010). Hence, there is an increasing interest in adopting complex system dynamic simulation models in health research (e.g., Galea et al. 2010; Sterman 2006; Trochim et al. 2006;

Mendez 2010) that allow for causal influence at multiple levels, the interaction among system variables, dynamic feedback, nonlinearity, and discontinuities. As explained by the Mendez (2010) system, modeling in public health can be seen as "a formal expression of our thoughts about the mechanisms that drive a real phenomenon […]. Models can provide a common framework to exchange ideas, crystallize our thoughts, highlight what we know and what we still need to find out, and experiment with possible solutions." In this respect, Galea et al. (2010) argue that epidemiologists and other health scientists can learn from other fields that have been applying such simulation approaches, such as systems biology, ecology and environmental sciences, and organizational science.

– *Scenario analysis of future health*: *A* system-based approach implies a lower emphasis on prediction but an accompanying greater emphasis on understanding the processes involved, acknowledging (inherent) uncertainties, and exploring alternative health futures. In sustainability science, scenario analysis is used as a tool to assist in the understanding of possible future developments of complex systems. Scenarios can be defined as descriptions of journeys to possible futures that reflect different assumptions about how current trends will unfold, how critical uncertainties will play out, and what new factors will come into play (UNEP 2002). In other words, scenarios are plausible but simplified descriptions of how the future may develop, according to a coherent and internally consistent set of assumptions about key driving forces and relationships (Swart et al. 2004). UNEP (2007), for example, provides an interesting guideline for developing scenarios. Looking at the main global-scale scenario studies, it can be concluded, however, that the health dimension is largely missing (Huynen 2008; Martens and Huynen 2003).
– *Transdisciplinary/participatory methods*: The omnipresence of uncertainty in complex systems allows for different valid views on the essence and functioning of these systems. The use of participatory/transdisciplinary methods is more exclusively linked to the emerging paradigm of post-normal science. As such, the involvement of actors from outside academia into the research process is also seen as a key component of sustainability science; it facilitates the integration of the best available knowledge and the co-production of knowledge, the identification and reconciliation of values and preferences, as well as creation of ownership for problems and solutions. Transdisciplinary, community-based, interactive, or participatory approaches have been suggested in order to meet these goals (Lang et al. 2012). Van Asselt and Rijkens-Klomp (2002) indicated, for example, that a multitude of participatory methods (e.g., focus groups, participatory modeling, scientist-stakeholder workshops, scenario analysis, and policy exercises) could be used to help assessors in structuring and eliciting tacit knowledge about and identifying perspectives on the complex issue being studied in the face of uncertainty.

Q: In addressing the complexity of "sustainability and health," which of the above methods is most useful? In what context?

4 Conclusion: The Need for Overcoming Barriers

To conclude, there is a growing acknowledgment of the multidimensional and multilevel causation of (global) health and the importance of a system-based approach, building on insights from sustainability science (Martens et al. 2011). Consequently, in our effort to assess the health impacts of global (environmental) change, we have to be aware of the limitations of the traditional reductionist approach; population health cannot be disassembled to their constituent elements and then reassembled in order to develop an understanding of the system as a whole. For example, this chapter shows that many of the factors within the climate-health system will interact with each other in ways that, as yet, may not be fully understood. Additionally, the outcomes of these interactions will vary across geographical locations but also across different disease outcomes (IPCC 2007; Cohen 2000; Sutherst 2004). We need to be moving away from discussion about the relative importance of climate change compared to other stressors, toward approaches that take possible synergies between different developments into account. As climate and non-climate factors work together, climate change cannot be seen as "a standalone risk factor" but rather as an amplifier of existing health risks (Costello et al. 2009). In order to avoid an escalation of health risk synergies, there is a need to better understand the multifaceted and complex linkages involved (Canfalonieri and McMichael 2006).

However, over the past several decades, questions of closely related cause-and-effect relationships have dominated epidemiological practice. Linear, reductionist approaches to research questions – focusing on proximate cause-and-effect relationships – have characterized much of what epidemiology has contributed to public health in the second half of the twentieth century (Soskolne et al. 2009). As a result, however, the exploration of long-term and complex risks to human health seems far removed from the tidy examples that abound in textbooks of epidemiology and public health research. There is a need to broaden the traditional view on disease causation in order to account for a multilevel understanding of disease etiology and the interrelations among these multiple health determinants (Galea et al. 2010). Such system thinking challenges the epidemiological concern with studying single causes of disease in isolation; by training, epidemiologists and public health researchers are less accustomed to studying causes within a systems context or addressing far longer time frames than current boundaries of the health sciences and the formal health sector (Martens and Huynen 2003).

A sustainability science approach to public health also implies recognizing that there is no single discipline or single operational method for systems thinking (Leishow and Milstein 2006). Such interdisciplinarity demands from health researchers to be particularly open to (learn from) the contributions of other traditions and approaches. Moving even beyond research collaborations among and above disciplinary boundaries, transdisciplinarity requires the involvement of and collaborations with nonacademic stakeholders from business, policymaking, and/or civil society. However, scientists taking a more conventional research perspective, such as traditional epidemiologists and health researchers, might question the reliability, validity, and other epistemological and methodological aspects of this type of research (Lang et al. 2012). From a more practical perspective, transdisciplinary research is a relatively new field, still in need of further enhancement in order to overcome its teething problems. Lang et al. (2012) recently published a very elaborate overview of the main challenges (and possible coping strategies) in conducting transdisciplinary research, including difficulties concerning design principles (e.g., lack of joint problem framing, selection of stakeholders/team members), methodological issues (e.g., conflicting methodological standards, discontinuous participation), and problems in the application of co-created knowledge (e.g., lack of transferability of results). They conclude that further developing the practice of transdisciplinary research requires "continuous structural changes in the academic system in order to build capacity for transdisciplinarity among students and researchers." The identified (practical) research challenges, as well as their conclusions about the need for capacity building, seem equally valid for conducting transdisciplinary research regarding the field of health and sustainable development.

Furthermore, the use of complex systems dynamic modeling approaches demands a shift from singling out a single cause as main research objective to a focus on understanding interactions and interrelations between various causal factors operating at multiple levels in order to gain insights into how these relationships (and feedbacks) contribute to the emergence of disease patterns within a population (Galea et al. 2010). These models need to be parameterized with observational (epidemiological) data, but this data needs to be applied in a creative way combining information from disparate sources and allowing for assumptions to be made in order to create simulation models in face of imperfect data and uncertainty about parameter values, relationships, and future developments. Accounting for system's complexity and uncertainty will also require a conceptual shift for epidemiology and public health – from statistical association models focused on observed effect estimates to simulations of complex dynamic systems of health determination in which we test scenarios under different conditions (Galea et al. 2010). Thinking critically about "what-if scenarios" entails moving from a predictive science in search for eliminating uncertainty to an exploratory science in the face of (inherent) uncertainties.

Hence, as stressed by Galea et al. (2010), unfamiliarity with methods and limited training in their implementation are probably enough reasons to delay epidemiologists' adaptation of systems approaches. Sterman (2006) even states that "faced with overwhelming complexity of the real world, time pressure, and limited cognitive capabilities, we are forced to fall back on rote procedures, habits, rules of thumb, and simple mental models." But – although health scientists might feel very comfortable with more reductionist approaches and we are, consequently, very slow adopters of systems thinking – we have to face the reality that we are dealing with complex real life health risks that we need to understand and address in the face of many sustainable development challenges.

Further Reading

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