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Science–policy challenges for biodiversity, public health and urbanization: examples from Belgium

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Abstract
Internationally, the importance of a coordinated effort to protect both biodiversity and public health is more and more recognized. These issues are often concentrated or particularly challenging in urban areas, and therefore on-going urbanization worldwide raises particular issues both for the conservation of living natural resources and for population health strategies. These challenges include significant difficulties associated with sustainable management of urban ecosystems, urban development planning, social cohesion and public health. An important element of the challenge is the need to interface between different forms of knowledge and different actors from science and policy. We illustrate this with examples from Belgium, showcasing concrete cases of human–nature interaction. To better tackle these challenges, since 2011, actors in science, policy and the broader Belgian society have launched a number of initiatives to deal in a more integrated manner with combined biodiversity and public health challenges in the face of ongoing urbanization. This emerging community of practice in Belgium exemplifies the importance of interfacing at different levels. (1) Bridges must be built between science and the complex biodiversity/ecosystem–human/public health–urbanization phenomena. (2) Bridges between different professional communities and disciplines are urgently needed. (3) Closer collaboration between science and policy, and between science and societal practice is needed. Moreover, within each of these communities closer collaboration between specialized sections is needed.

Keywords: biodiversity, ecosystem services, public health, urbanization, science–policy interface, community of practice, complexity

1. Introduction

The major challenges facing humanity in the 21st century are closely interlinked and increasingly globalized. At local, regional and global scales the crises in health, food and nutrition security, water, energy, climate change, biodiversity loss and poverty frequently overlap in both root and proximate causes, in their various impacts, and in terms of the policy and practical approaches needed to address them and to effect sustainable long term solutions (e.g. UN 1992, McMichael 1993, MA 2005, Dreher *et al* 2008). Walker *et al* (2009) have highlighted deficiencies in global institutional approaches to these issues, and have called for greater collaboration and cross-linking between actors in civil society, business and governance, supported by greater 'local appreciation of shared global concerns'. This is a fundamental challenge for sustainable development, demanding improved dialogue between sectors and the integration of perspectives, policies and strategies between social, environmental, economic and cultural arenas, and creation of new institutional frameworks.

Against this background the linkages between the biosphere and human health and well-being have become of increasing importance in international science and policy in the past two decades, with new interdisciplinary and 'transdisciplinary' fields emerging to address the gaps in knowledge and action based on ecosystem approaches to health (or *ecohealth*), (e.g. Lebel 2003, de Plaen and Kilelu 2004). This includes the concepts of *One World, One Health* (Wildlife Conservation Society) and *conservation medicine*, and initiatives such as the *EcoHealth Alliance* (EcoHealth Alliance), *Co-operation on Health, and Biodiversity* (COHAB) and the *DIVERSITAS ecoHealth project* (DIVERSITAS ecoHealth). These approaches build on the concept of the ecosystem approach to biodiversity conservation promoted by the UN Convention on Biological Diversity (CBD), which aims to account for the interactions between various levels of biological complexity and recognizes that 'humans, with their cultural diversity, are an integral component of ecosystems' (CBD COP Decision V/6); as such, ecosystem approaches to health are systemic approaches to population health that recognize intimate links between the health of the biosphere and the health of human communities, and frequently incorporate perspectives of ecology, human and veterinary medicine, agriculture, economics, sociology, and aspects of risk assessment, engineering, and conflict resolution. To date much of this work has, for the most part, been led from within the environment and conservation biology disciplines, fronted by environmental research institutes and NGOs, and intergovernmental environmental agencies, frequently building on the findings of the Millennium Ecosystem Assessment (MA) (MA, MA 2005, Hales *et al* 2004, Hales and Corvalan 2006) and related processes. However, as the science on these issues has progressed, so too has the understanding within the medical science and healthcare community of how major public health issues and emerging health threats may be associated with global environmental change, and how interactions with ecological systems affect disease risks, health outcomes and the efficacy of public health management strategies (see for example Dobson and Carper 1993, Soskolne and Bertollini 2002, WHO 2005, Chivian and Bernstein 2008a, WHO 2011).

In 2000, a commentary in *The Lancet* medical journal (as part of a special series on future health challenges) highlighted the many challenges facing healthcare in the new century, arguing that partnerships with actors outside of the health sciences would be critical, and calling for commitment to 'a broader view of public health, and to values of equity and ecological sustainability' (Beaglehole and Bonita 2000). The constraints to such systemic and cross-sector approaches are numerous and complex. These include cultural, resource and political barriers, knowledge gaps, and differing temporal scales of operation. Campbell-Lendrum (2005) identified three core difficulties that hinder such engagement by the health sector on environmental issues—a lack of awareness of the relevance to health, a methodological approach focused on discrete cause–effect relationships rather than systemic issues, and little input to processes addressing the environmental root causes of health problems. Therefore, realizing these approaches requires development of a strong evidence base, a mutual understanding of perspectives between sectors, common frameworks for assessment, and practical collaborative strategies based on an appreciation of shared risks and opportunities. The concept of *ecosystem goods and services* (referring to the benefits which ecosystems provide to society, and often considered together simply as *ecosystem services*) has been important in helping to bridge these gaps, and serves as a framework on which to build ecosystem approaches to health and well-being. In particular, the outputs of the MA have helped to conceptualize the links between ecosystem services and well-being (Alcamo *et al* 2003, MA 2005), highlighting current knowledge, identifying risks of ecosystem change, and suggesting areas for future research. Whilst the precise relationship between biodiversity and the delivery of ecosystem services is not always clear and is often contentious, not least in terms of the precise connections between biodiversity and services relevant to health, in a general sense it is widely accepted that biodiversity is important for the key traits of resistance and resilience in ecological systems and as such underpins ecosystem services (CBD 2010). Although the attribute of 'diversity' is not necessarily essential to the delivery of certain ecosystem services in every scenario—for example, a monoculture forest plantation might perhaps supply as much or more timber as a native mixed woodland of similar size—diversity helps to secure the sustainability and flow of multiple ecosystem services, and supports adaptation to environmental change (that same monoculture might be more susceptible to disease or drought, and provide less in terms of other services such as pollination and food resources; see for example Gamfeldt *et al* 2013). Whilst still a very young and evolving field, the study of ecosystem services is progressing rapidly, with particular attention paid in recent years to the economic aspects of ecosystems, and the economic policy implications of ecosystem change and biodiversity loss. This has included global assessments (TEEB 2011) as well as regional and national scale studies including several within Europe (e.g. Bullock *et al* 2008, Ticker *et al* 2010; Bateman *et al* 2011, ten Brink *et al* 2011). In contrast, despite the growing awareness of linkages between biodiversity, ecosystem services and public health, the health dimension remains comparatively undervalued in policy and practical contexts, even within recent economic studies (the above referenced works, for example, pay little attention to economic aspects of biodiversity-related health issues, though Bateman *et al* (2011), for the UK National Ecosystem Assessment, attempt to link the two fields for some health issues).

However, in recent years there have been some significant developments in international policy and in local, regional and global responses towards the integration of biodiversity and human health. In 2010, the 10th Conference of the Parties (COP) to the Convention on Biological Diversity adopted a decision mandating direct interaction between the Secretariat of the Convention and the World Health Organization (CBD COP Decision X/27), committing for the first time to forging a partnership with the WHO. Also, in outlining a new strategy for the period 2011–2020, the COP urged that National Biodiversity Strategies and Action Plans should work to enhance the contribution of biodiversity to human health and well-being. Further decisions to build upon this action were taken at the 11th CBD COP meeting in 2012. That year also saw the links between health and biodiversity recognized at the Rio +20 UN Conference on Sustainable Development, where a discussion document titled *Our Planet, Our Health, Our Future* (jointly prepared by WHO and the secretariats of the three Rio Conventions—the CBD, the UN Convention to Combat Desertification and the UN Framework Convention on Climate Change) was presented by the WHO Director General Margaret Chan, highlighting the links between global environmental agreements and global health concerns (WHO 2011). The same year, the UN-mandated Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) was launched, with a specific remit of strengthening the science of biodiversity and ecosystem services and their importance to human well-being, including health, in order to facilitate informed decision making in environmental, economic and social policy. However, the involvement of the health sector in progressing sustainable development is still poor (Langlois *et al* 2012); critically, leadership from global institutions such as the World Health Assembly, to promote dialogue with the biodiversity sector and greater integration of health and biodiversity concerns from local to regional levels, is lacking (COHAB 2010). Clearly, many barriers to mainstreaming an ecosystem approach to health remain.

In this paper we illustrate the challenges of integrating efforts to address problems involving biodiversity, public health and urbanization. To do this, we take examples from Belgium, one of the most densely populated and urbanized countries in the world. Going on, we discuss an emerging community of practice in Belgium. Since 2011, actors in science, policy and the broader Belgian society have launched a number of initiatives to deal in a more integrated manner with combined biodiversity and public health challenges in the face of on-going urbanization. First, though, we provide additional background on the interfaces among these sets of challenges.

A note on definitions: Arriving at a precise definition for *biodiversity* that can meet the current range of scientific, economic and policy needs has proved difficult, compounded by the fact that much of the world's biodiversity has yet to be discovered or described (e.g. Swingland 2001, Feest *et al* 2010). In this paper, we follow the definition provided in the text of the UN Convention on Biological Diversity (CBD) and now widely accepted and used in policy contexts, i.e. the variability among living organisms from all sources including *inter alia* terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part, including diversity within and between species, and of ecosystems. We also acknowledge recent debate on what constitutes a useful definition of health. The widely utilized definition from the Constitution of the WHO is 'a state of complete physical, mental and social well-being, and not merely an absence of disease or infirmity'; some commentators have questioned whether this definition is still sufficient in an increasingly globalized world and in the face of pervasive human impacts on the global environment, and have advocated that the definition should also account for the ability to adapt to health challenges (e.g. Lancet 2009, Huber *et al* 2011). This focus on adaptation has strong correlations with the concept of ecosystem health, with its notions of resistance and resilience (Costanza 1992, Rapport *et al* 1998), and can be particularly useful in terms of understanding the importance of biodiversity to sustaining health and well-being in the context of global change.

1.1. Biodiversity and public health

According to McMichael (2009), 'Human population health should be the central criterion, and is the best long term indicator, of how we are managing the natural environment'. Environmental philosophers and others may question the valuation of human life over all other life in this assertion, as well as the implicit assumption that 'we' can truly manage the natural environment. Human population health nonetheless is an important criterion for efforts by institutional and other actors to guide human action in the natural environment. Whereas human health and social well-being were once largely seen as an aim and outcome of economic growth, today they are more broadly understood as a prerequisite and fundamental principle of sustainable development (McMichael 2002, 2006, von Schirnding 2002, Martens 2002).

New types of diseases and public health issues have appeared in the last century, including the emergence or re-emergence of pathogens, new environmental hazards and increased risks of natural disasters, and changes in food regimes. The WHO has estimated that one quarter of the global burden of disease in humans, disproportionately felt in the developing world, is due to environmental change (Prüss-Üstün and Corvalán 2006). The MA synthesis report for the health sector (WHO 2005) outlines several linkages between ecosystems and health, providing a review of the health implications of ecosystem changes identified in the MA, and the actions required to address these.

However, the links between biodiversity and human health are varied and complex and not always certain. Some clear linkages can be demonstrated, for example the importance of biodiversity to traditional and modern medicinal practice, and the utility of various species for medical research, as sentinels of emerging health risks, and as models for investigating human disease (Harvey 2008, Newman *et al* 2008, Tabor and Aguirre 2004, Chivian and Bernstein 2008b, Cox 2009, Li and Vederas 2009). Genetic and species diversity is also the cornerstone of food production, and can play an important role in addressing issues of nutrition security including certain disease risks (e.g. obesity, diabetes and other diseases of affluence) through dietary improvements (Wilby *et al* 2009, Johns 2003, Frison *et al* 2006, Toledo and Burlingame 2006, Hillel and Rosenzweig 2008, Burlingame *et al* 2009, Burlingame and Dernini 2012). By underpinning certain critical ecosystem services, biodiversity also plays a role in safeguarding air quality and access to fresh water (see for example: Rockström *et al* 1999, Ostroumov 2002, Melillo and Sala 2008, Cardinale 2011); and plays a role in disaster risk reduction and in supporting the response to emergencies and climate change adaptation (Sudmeier-Rieux *et al* 2006, Colls *et al* 2009, Parmesan and Martens 2009). Furthermore, diversity of life in natural environments may enhance experiences that promote stress reduction, support the development of cognitive resources, stimulate social contacts, attract people for physical activity, and support personal development throughout an individual's lifespan (Kaplan and Kaplan 1989, Kellert 2008, Skevington 2009, Hartig *et al* 2011). Moreover, recent studies show that declining (contact with) some forms of life may contribute to the rapidly increasing prevalence of allergies and other chronic inflammatory diseases among urban populations worldwide (Rook 2010, von Hertzen *et al* 2011, Hanski *et al* 2012). Biodiversity thus can have an important contribution to both public health related ecosystem services and in reduction of health risks.

One area of intense scrutiny is the relationship between biodiversity and infectious disease, and how ecosystem change and biodiversity loss may affect the ecology of disease organisms and the dynamics of pathogen–host interactions. The emergence and spread of certain pathogens from wildlife to livestock and/or humans, and related social and economic costs, has been well documented—these diseases include HIV, hanta virus, avian influenza, Lyme disease, malaria, Dengue fever, Leishmaniasis, Nipah virus and Ebola (Peixoto and Abramson 2006, Molyneux *et al* 2008, Marsh Inc. 2008, Thomas *et al* 2009, Lindgren *et al* 2012). Several studies have determined that biodiversity reduces the risk of infectious disease emergence or spread, while its loss or unsustainable exploitation can increase such risks (e.g. Pongsiri *et al* 2009, Keesing *et al* 2010, Johnson *et al* 2013). The dynamics, however, are complex and probably system-dependent, and high biodiversity does not necessarily reduce disease risk in all situations (e.g. Randolph and Dobson 2012, Kilpatrick and Randolph 2012). Nevertheless, land-use change and ecosystem disruption are well recognized factors influencing disease emergence. In a study examining incidences of disease emergence worldwide, Jones *et al* (2008) established that there has been an increase in disease emergence and an increasing prevalence of zoonotic diseases since 1940. They also established that areas of likely high-risk for novel emerging infectious diseases correlated with areas of high biodiversity, and with areas of high human population density. Another issue associated with population density is the significant health threat posed by antimicrobial resistance. Amongst the risk factors for emergence of resistance is pollution from agriculture and from urban areas. Drug resistant organisms present in the environment can be picked up and carried by wildlife and by feral animals, potentially increasing human health risks in urban areas (e.g. Radimersky *et al* 2010, Allen *et al* 2010).

Whilst providing a compelling public health incentive for collaboration, the importance of biodiversity to health also presents an important argument for nature conservation. Chivian and Bernstein (2008a) have reasoned that the human health dimension—which impacts widely on social, economic, cultural and environmental arenas—represents a significant opportunity to push for more effective public and political engagement in conservation. This also, by extension, presents a significant opportunity for sharing of ideas and resources across sectors, with the potential for integrated policies and strategies that can more effectively achieve and sustain multiple goals. From the perspective of adaptation, the loss of biodiversity, by affecting the sustainability and flow of ecosystem services, can be said to limit our capacity to adapt to future health challenges, whether they arise from novel pathogens, emerging non-communicable disease threats or natural hazards, whilst its conservation and sustainable use may be seen as an insurance policy against such challenges.

1.2. The interplay between biodiversity, public health and urbanization

Whilst the root causes of ecosystem change impacting on health are varied, population growth and related demand for land and natural resources are certainly primary amongst them. The related on-going trend towards urbanization worldwide makes the challenge of linking biodiversity and public health even more difficult, and presents certain unique challenges for science and governance. Urbanization has significant impacts on biodiversity (Rees 1997, Barton and Grant 2006, Seto *et al* 2012), an issue which receives specific focus at the CBD COP meetings and other policy arenas; (de Oliveira *et al* 2010, EEA 2009), with suggestions that more than 60% of the area projected to be under urban infrastructure by 2030 has yet to be built (CBD 2012). Cities and other densely populated urban areas are net

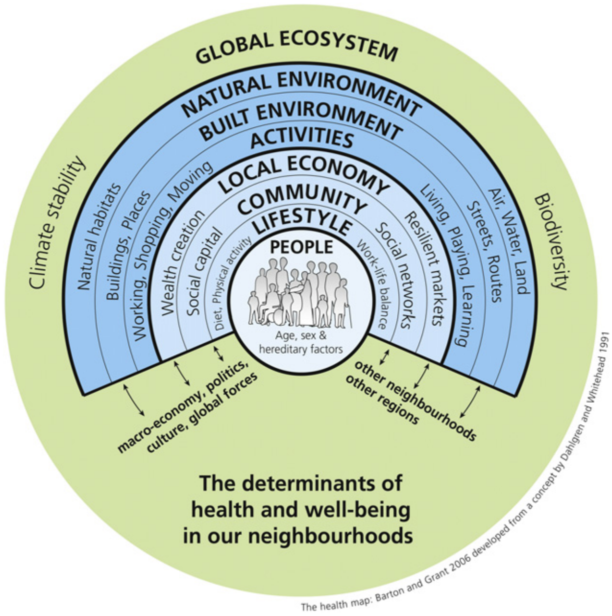

Figure 1. The 'settlement health map'. Reproduced with permission from Barton H and Grant M 2006 A health map for the local human habitat *J. R. Soc. Promot. Health* **126** 252–3. See also Dahlgren G and Whitehead M 1991, version published in Whitehead M 2005 Tackling inequalities: a review of policy initiatives *Tackling Inequalities in Health: An Agenda for Action* ed M Benzeval, K Judge and M Whitehead (London: Kings Fund).

importers of ecosystem services—e.g. for food, water, and for assimilation of wastes including emissions associated with climate change. Urbanization has been described as both inherently unsustainable and the greatest opportunity for sustainable development (Rees and Wackernagel 2008)—so how can both nature and human well-being be sustained when more and more people live in cities placing increasing demand on finite living resources (see also Soskolne and Bertollini 2002, Stephens 2012)? What conceptual frameworks should be utilized to connect the range of disparate disciplines involved whilst also accounting for various societal choices and cultural diversity within urban areas?

By 2035 a majority of people on all settled continents are expected to live in urban areas, due to greater migration inwards and the physical expansion of those areas to accommodate natural outward growth (United Nations Population Division 2010). The links between human settlements and public health are of long standing interest in land use planning and social policy (see figure 1), though it has been argued that these linkages have been largely overlooked by planning systems and related health and environmental assessments in recent decades (Barton and Grant 2006, Barton 2009, Carmichael *et al* 2012). Similar to Campbell-Lendrum's reasoning (2005), Barton (2009) contends that the reasons for this include the failure of planning systems to consider the perspectives of public health practitioners, and a lack of engagement of public health practitioners in planning policy. Therefore, considering the current and projected future rates of urbanization and migration to cities, the specific dependences of urban communities on external biodiversity and the impacts which urban biodiversity can have on the health of urban citizens, the need for an integrated approach to the development and management of urban infrastructure, including living natural resources, is pressing. The concept of 'green infrastructure' (the managed and unmanaged biodiversity within urban areas that may provide ecosystem services) has emerged as an attempt to help address this point. This field has evolved rapidly with significant developments in concept and practice in recent years, including efforts to ensure that urban green spaces contribute to improving human health, e.g. through improved water quality management associated with sustainable drainage systems, by providing opportunities for recreation and social interaction, as well as through development of urban food gardens (Bolund and Hunhammar 1999, Tzoulas *et al* 2007, Wittmer *et al* 2012, Niemelä *et al* 2011, Grant 2012).

1.3. Scientific challenges

Whilst the need for integrating biodiversity and ecosystem approaches into the health sector is evident, it is equally important that the biodiversity sector for its part recognizes the potential impacts—positive and negative—of conservation policies and activities on human well-being. Lyytimaki and Sipila (2009) have argued that it may be counterproductive to frame ecosystem services for green planning and management only in positive terms, without paying due attention to negative impacts—or ecosystem disservices—that biodiversity may produce in urban areas. For example, pollen spreading from urban vegetation may trigger distress in some with allergies, whilst urban tree planting can cause nuisance e.g. with damage to infrastructure caused by invasive roots. It may be argued, however, that these concerns are not necessarily a result of diversity *per se*, and may be an outcome either of specific choices in the design or management of urban areas and/or their green infrastructure (comprising as they do entirely artificial ecosystems), or simply a consequence of exposure to inherent natural nuisances not unique to urban areas. Regardless, habitat management in urban areas should take into account both ecosystem services and potential nuisances and consider trade-offs where appropriate.

Interdisciplinary science can provide options for such management, and society at large can then take informed decisions in choosing among those options. Ernstson (2013) states that these decisions must also account for issues of social justice—e.g. the need to ensure equity in decision making, accounting for varying costs and benefits of urban resource management that may be experienced by different urban communities—and has highlighted issues of conflicting societal choices in terms of how urban ecosystems and associated benefits may be valued. Cutts *et al* (2009) have also highlighted the issue of equity and justice in terms of access to urban ecosystem services. Considering how specific patterns of urban design can restrict access to ecosystems that may support health, or make their availability more important, this is surely another important dimension to be addressed. Additional scientific research will inevitably be needed to better understand the interplay between urbanization, biodiversity and public health. For example, knowledge about how urban landscapes affect the interaction between wildlife and pathogens is not well established (Bradley and Altizer 2007); and though the value of green care approaches to public health are more and more investigated, the effectiveness of green care interventions is still controversial (Sempik *et al* 2010). Addressing these challenges will require further research, greater use of conceptual models that cross disciplinary agendas (e.g. figure 1), and greater involvement of practitioners in urban planning and associated assessments.

1.4. New institutional science–society arrangements

Whilst there are specific barriers that hinder the natural cross flow of ideas between various scientific disciplines concerned with health-biodiversity linkages, there are also particular issues at the interface of science and public policy. How should scientific assessments be translated into effective public policy? How should societal choices account for issues of scientific complexity and uncertainty? How can valuation methodologies (e.g. of the importance of biodiversity to health and well-being) account for differing cultural perspectives, differing policy goals, and a variety of potentially conflicting community needs? The challenge at the science–society interface consists in developing adequate interfaces, but also in dealing with its intrinsic complexity as a social interface. Long (2001) defines a social interface as 'a critical point of intersection between different life worlds, social fields or levels of social organization, where social discontinuities based upon discrepancies in values, interests, knowledge and power, are most likely to be located'. Interfaces lead to realities that have to be recognized as complex by practitioners, scientists, policy makers and funding bodies.

According to Ernstson *et al* (2010a), not only does the scientific understanding of urban ecosystem services need further development, but so also do the governance aspects: 'In contrast to other urban services like medical care and public transport, there has been a deep neglect of research and theorization regarding the governance of ecosystem services in urban landscapes'. There is an urgent need for multi-scale and multi-actor collaboration as it concerns a complex process in which 'no actor, or set of actors, can have full knowledge or full control' (Ernstson *et al* 2010b). This requires experts to take up another role in relation to policy making, to leave their comfort zones as data and knowledge providers, and to become 'connective actors across scales and sectors', a process which also requires incentives from funding agencies to allow scientists to shift focus from traditional scientific routines to more practice-oriented collaborative research. Ernstson *et al* (2010b) refer here to developments in modern governance, in which traditional science 'speaking truth to power'-approaches (Jasanoff 1990) are no longer the only option for addressing complex societal sustainability challenges.

An important aspect of ecosystem governance and a strong rationale for the further development of science–policy interfaces is the need for policy to incorporate different types of knowledge in decision-making processes.

A 'science–policy interface' (SPI) can be defined as: 'relations between scientists and other actors in the policy process which allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision making' (Van den Hove 2007, Sarkki *et al* 2012). The most prominent example in the field of biodiversity is the current institutionalization of the IPBES. There has been some concern that the range of knowledge and stakeholders in these international efforts should be broadened to include voices outside of strict boundaries of peer-reviewed science and policy making communities—what Turnhout *et al* (2012) in a comment in *Nature* referred to as 'elite actors, from natural scientists to national governments'—to reflect (for example) experiences and knowledge from local and indigenous communities and other local actors from non-environment sectors. Such concern raises questions regarding value judgements and the role of science in policy making, and connects to issues highlighted by Lang *et al* (2012) and Ernstson (2013)—e.g. how do we address differences in perspectives on the value of natural assets between communities? How or to what extent do we consider lessons or perspectives from local knowledge if they are not verified by scientific methods? And how far should science go towards supporting specific values? Addressing such questions requires new approaches to knowledge sharing, and development of frameworks for open dialogue that promote mutual understanding of various concerns, drivers, values and needs. Centring the dialogue on the concept of human health and well-being, supported by more robust science on the linkages between biodiversity and health, may be one important means of addressing these issues.

Adaptive co-management (Armitage *et al* 2007, 2008) is a new example of governance related to ecosystem management. The core idea of adaptive co-management is that ecological and social complexity make it difficult if not impossible to identify *a priori* 'the' best management approach. Learning by doing is crucial in adaptive co-management, as are experimenting and adjusting management practice based on experience and knowledge gained along the way. In addition, adaptive co-management favours the inclusion of multiple actors.

2. The example of Belgium

Nature conservation presents huge challenges in a country like Belgium, because of its complicated governmental policy landscape (appendix A), but especially because of its extensive urbanization. Belgium has one of the world's most dense road networks, and it is in the top 30 of most densely populated countries (United Nations Population Division 2010). High urbanization rates pose several different challenges to biodiversity and public health, particularly regarding infectious diseases, as illustrated by the three examples that follow. High urbanization also implies that the population has relatively limited access to the natural environment, and this has consequences for public health that will be discussed below.

2.1. Of urban foxes, mosquitoes, and avian influenza

2.1.1. Urban foxes as disease vectors. Recent concerns about the spread of disease organisms by foxes (*Vulpes vulpes*) in Belgium provide a useful example of the interactions between biodiversity, health, urban management and land use planning. At the end of the twentieth century, European fox populations increased remarkably both in area and in density (Chautan *et al* 2000). In Belgium, this evolution was most striking in Flanders as in this region foxes had been totally absent in many areas for several decades (Van Den Berge and De Pauw 2003). The new and quite surprising appearance of foxes in a region with a very high human population density soon gave rise to increasing concern (Van Den Berge 1995). In addition to damage to poultry and game stocks, foxes are widely associated with certain zoonotic diseases, with rabies risk being one issue of particular public concern; however, thanks to successive rabies vaccination campaigns by oral immunization from 1989 that disease was eradicated from Belgium (Van Gucht and Le Roux 2008), the country being officially declared rabies free in 2001 (Brochier *et al* 2001).

In the meantime, however, another and frequently more dangerous zoonosis directly linked to foxes appeared to emerge: alveolar echinococcosis, caused by the larval stage of the small fox tapeworm *Echinococcus multilocularis*. Foxes, domestic dogs and other canids are definitive hosts for the parasite, carrying the adult stage in their intestines. Worm eggs are released into the environment with the faeces, and they can then be taken up by an intermediate host, such as one of several rodent species, especially Microtidae. (e.g. grassland voles, muskrats). Humans also can become infected through the oral ingestion of *E. multilocularis* eggs. If untreated, the continuous larval cyst development of the parasite within the human body can be fatal—making alveolar echinococcosis one of the most dangerous zoonoses in Europe. Since the growth of the European fox populations, it seems that also the parasite has extended its range.

Flanders cannot be considered as an endemic region yet (Van Gucht *et al* 2010), but the threat posed by infected foxes seems specific to Flanders for two reasons. First, it seems quite plausible that the further spread of *E. multilocularis* will be hampered by a relative rareness of Microtidae as the most appropriate intermediate host species. Muskrats have nearly been eradicated thanks to the implementation of an efficient pest control technique, whereas grassland voles can hardly find a suitable habitat in the intensively cultivated Flemish agricultural areas. Indeed, contrary to fox diet studies done in other countries, in Flanders the genus *Microtus* appears not to be the main food item but is instead replaced by the brown rat (*Rattus norvegicus*) (unpublished data from 1996–2005). The latter species, living close to human settlements, is omni-present in Flanders as a consequence of extensive settlements even in relatively rural areas. This brings us to the second reason why situation may be specific to Flanders. When foxes are present, they quickly become well adapted to an urbanized environment and often dwell in close proximity to residences and gardens, facilitating the potential transmission of zoonoses. 'Urban foxes', however, seem to pose little risk, due to an almost complete absence of appropriate intermediate hosts where they live, while 'rural foxes' pose little risk due to the limited contact they have with humans. Instead, the so called 'village and small town foxes' generate the most critical situation for transmission of *E. multilocularis* (Janko *et al* 2011). In Flanders, the fox habitat and human habitat are nearly entirely overlapping. Therefore, in the case of strongly increasing *E. multilocularis* prevalence in foxes, actions to prevent human infection are called for. These could include large scale baiting with a convenient vermicide product

It is important, however, to address the problem (*E. multilocularis*) and not kill the messenger, so to speak. The overlap of fox habitat and human settlement potentially also has positive health related implications in Flanders, as foxes help to control the populations peaks of brown rats, and other small rodents, and this may in turn help to prevent possible emergences of Lyme disease, for which ticks act as the vector and small rodents act as reservoir hosts (Levi *et al* 2012). Furthermore, the recent findings of *E. multilocularis* infections in other wild species in Europe, including beaver and wild boar, indicate that other species may introduce, maintain or re-establish the parasite in areas which may lead to transmission to people, pets or foxes and thus may ultimately influence the disease cycle (e.g. Boucher *et al* 2005, Barlow *et al* 2011). Another important consideration is that urbanization of foxes and associated zoonoses is in large part related to encroachment of human settlement on wildlife habitat and to urban environmental health management. For example, Rabinowitz and Gordon (2004) have reported on a case of zoonotic scabies infection (*Sarcoptes scabiei*) in the United States, associated with interactions with wild foxes originating with a sick fox found on a golf course. They suggest that identification of initial infection ahead of an outbreak—e.g. in this case an initial human case and a noted increase in infections in domestic dogs—could serve as 'sentinel' events, indicating a possible increased likelihood of infection in a community, from which appropriate public and veterinary health announcements or other measures could be taken.

In the case of echinococcosis in Belgium (and elsewhere), greater interaction amongst veterinary and public health practitioners, environmental health officers and urban managers could help to not only manage outbreak risks but also serve as an indicator for monitoring the effectiveness of preventative strategies (e.g. see Hegglin and Deplazes 2013). Furthermore, the inclusion of ecologists and urban planners could help identify areas where new or revised approaches to ecosystem management, in order to limit human–wildlife interaction, might be warranted. Integrated multidisciplinary approaches may be particularly important in the forward planning process, including in health-inclusive Environmental Impact Assessment, identifying where particular development may lead to increased human–wildlife interaction and related health risks, and helping to identify appropriate measures to avoid or reduce zoonoses risk.

2.1.2. Mosquitoes. After the eradication of malaria in northern Europe in the mid-20th century, little attention has been paid to the distribution and biodiversity of mosquitoes despite their importance in disease transmission (WHO 2004). While the number of mosquito-borne diseases and their incidence in Europe remain quite low, there are upward trends in incidence and geographical spread of several of these diseases (Hendrickx and Lancelot 2010). Over the last years, autochthonous transmission events of Chikungunya, Dengue, West Nile and malaria have been reported from Europe. Increased globalization, changing landscape management and changing socio-economic behaviour create suitable conditions for the (re)emergence of mosquito-borne diseases across Europe (Tatem *et al* 2006, Lines 2007, Pysek *et al* 2010); factors which affect the occurrence, distribution or density of mosquito vectors—including climate change and ecosystem change—are also of particular interest (e.g. Arinaminpathy *et al* 2009, Bezirtzoglou *et al* 2011, Rohr *et al* 2011).

To remedy the limited knowledge on current mosquito biodiversity and distribution in Belgium, a national inventory was started in 2007 (MODIRISK). This inventory is based on a specific sampling strategy that allows a rapid overview of mosquito diversity (Versteirt *et al* 2012). The acquired knowledge on local species occurrence has been used to develop mosquito species distribution models and to assess the actual countrywide transmission risk of mosquito-borne diseases, taking into account possible interference by several ecological, biological and socio-economic factors. Ultimately species co-occurrence maps were created that can be used to delineate zones of higher risk on nuisance and/or disease transmission.

The study highlighted a number of important events. First, an increased distribution range and adaptation to a more urbanized environment was observed for several indigenous vector mosquitoes such as the common house mosquito (*Culex pipiens*) and *Anopheles plumbeus*. The latter species is highly anthropophilic and in some urbanized areas, high abundances are causing severe nuisance with highly allergic skin reactions due to the bite of the species. Moreover, recent outbreaks of West Nile in Greece, Romania and Spain (Papa *et al* 2010, Santa-Olalla Peralta *et al* 2010, Sirbu *et al* 2011) and autochthonous cases of malaria in Belgium, Germany and the UK (Blacklock 1921, Shute 1954, Krüger *et al* 2001), indicate the potential for both mosquitoes to transmit diseases. Secondly, wetland re-alignment (as part of large scale flood risk management) has created suitable habitats for mass emergence of nuisance and/or vector species such as *Ochlerotatus caspius* and *Coquillettidia richiardii*. These newly created habitats are potential breeding sites for anopheline mosquito populations, leading to an increased chance of malaria transmission.

The MODIRISK project proposes a targeted cost-effective monitoring regime of these species (Versteirt *et al* 2009, 2012). One of the direct outcomes of this multidisciplinary project has been the increased awareness of the authorities on the risk posed by exotic and indigenous vector species, which has led to the establishment of an inter-ministerial working group 'Exotic Mosquitoes' (federal environmental department).

This project highlights the importance of ecosystem approaches to vector-borne disease risks around human settlements, and suggests several other important areas for further research. For example, the precise links between host and vector diversity, landscape management and human health risks in Europe are unclear and require detailed study. Work in the United States has highlighted links between mosquito-borne disease risk and biodiversity in the wider landscape: research by Ezenwa *et al* (2006) has suggested that diversity of passerine bird species reduces circulation of West Nile virus in the wild and therefore could reduce human disease risk, while Zielinski-Gutierrez and Hayden (2006) suggest that changes in urban and periurban landscapes (e.g. through new development) can affect the geographical distribution of West Nile virus, and that underlying attitudes towards natural landscapes and biodiversity should be taken into account when considering disease risk and response strategies.

2.1.3. Avian influenza. The relationship between biodiversity and the emergence of infectious diseases in domestic animals is as yet poorly described, but it is particularly important when those diseases have the potential to harm humans. The example of avian influenza is illustrative.

Low pathogenic avian influenza viruses (LPAIV) are naturally present in the wild avifauna with a high diversity of types and subtypes. Diverse bird species therefore suffer infections that have a low clinical impact. Highly pathogenic avian influenza viruses (HPAIV), in contrast, have a low diversity, with epidemics usually involving only one subtype and usually affecting a limited number of domestic species, though with a high clinical impact. This epidemiological system thus shows a high stability and a low impact when there is both a high diversity of hosts and pathogens.

Epidemiological problems arise when diversity in hosts and pathogens become reduced. When an LPAIV is introduced into intensive poultry production systems, it goes through fast selection. Within the high-density, genetically similar, susceptible host populations of poultry production systems fast selection can amplify virulent pathogen strains (Mennerat *et al* 2010). A new, virulent pathogen can then escape the leaky confines of the intensive production units to invade other livestock and wild species, and potentially infect human populations. It has been shown that HPAIV can be produced from low pathogenic strains following consecutive passages through genetically homogenous chickens (Ito *et al* 2001). Panzootic HPAI H5N1 emerged in China in 1996 (Li *et al* 2004) following several years of intensification of chicken and duck production. Closer to Belgium, an HPAIV H7N7 virus emerged in the Netherlands in 2003 and spread to Belgium, both countries having very intensified poultry production systems. Whilst HPAI H5N1 continues to circulate in several countries in Asia, the 2003 H7N7 epidemic was quickly controlled in Belgium and the Netherlands. Nonetheless, the example highlights the fact that the risk of emergence of novel HPAIV subtypes is far from being limited to Asian contexts. Whilst the specific roles of intensive production systems in the emergence of novel strains of pathogen are not well understood and would need further investigation, CAST (2005) concluded that intensified livestock production systems, characterized by a low diversity of hosts, created ideal conditions for rapid selection and amplification of highly pathogenic strains of disease agents.

Ecosystem approaches have been particularly important in identifying the risks of spread of HPAI in Europe. Kilpatrick *et al* (2006) found that identification of H5N1 in 20 of 23 European countries was most likely attributable to migratory birds. Waterfowl, particularly ducks, have been identified as major carriers, owing to their tendency to congregate in large multi-species flocks on water bodies or wetland where the virus can circulate, and the fact that many species are resistant to HPAI infection, providing opportunities for genetic recombination and widespread dispersal (e.g. Rapport 2006, Kim *et al* 2009). The presence of the virus in wildfowl also creates a risk of spread to other wildlife species, with reports from Sweden and Germany of infection in mink and pine marten following predation of waterfowl (ECDC/Eurosurveillance, 2006a, 2006b). This has led to intensified biosecurity concerns about interactions between wild species and domestic poultry and livestock, and in extreme cases there have been calls for large scale culling of wildfowl. Conservation organizations, UNEP, FAO and WHO have urged caution in restraint in this regard (International Task Force on Avian Influenza 2006), and it has been suggested that adopting the ecosystem approach at the landscape level—preventing and reversing degradation of habitats enhancing measures to segregate wildfowl from domestic animals, and greater co-operation between human health, veterinary and ecological agencies in disease surveillance and land management, are key to minimizing significant health and economic risks from the disease (Rapport 2006). Such approaches may have particular relevance in Belgium, owing to the particular structure of the Belgian poultry sector, and the location of the country on migratory pathways for large numbers of wildfowl (Vandendriessche *et al* 2009). This raises additional concerns about the spatial and ecological relationships between natural and artificial water bodies (including lakes and ponds in public parks), agricultural lands and human settlements., further highlighting the need for ecosystem based approaches to disease risk.

2.2. Urban green space and health

Access to green space can yield diverse benefits for public health. For example, Van Herzele and de Vries (2012) compared two neighbourhoods in the city of Ghent, and they registered greater happiness and satisfaction in the greener neighbourhood. Yet many urban residents may not be able to realize such benefits. Van Herzele *et al* (2004) showed that in six major Flemish city centres, more than one third of the inhabitants did not have easy access to green spaces (i.e. within 800 m distance). Access is partly limited due to infrastructural barriers, such as highways. Access is also unequally distributed amongst social classes; low income groups have less access. The study also concluded that although attention to the need for urban green space has increased, existing urban green space is under pressure from land conversion or decrease in natural quality. Accordingly, initiatives have recently been taken to support urban planning that enables and maintains contact with nature. Two of them will be briefly outlined here.

In January 2011 the Flemish Agency for Nature and Forest (ANB) started a strategic project, *Green in the City*, manifesting the Flemish ambition to become a green and dynamic urban region by 2020. The project hopes to instigate knowledge-based networking, inspiring a diversity of actors to establish more green space and other aspects of nature in urban areas. A central part of the project is sharing the knowledge on parks and green space management which has been built up over the years, bundled in technical management tutorials on a variety of topics, including but not limited to trees, grassland, herbs, water, and paths and pavements. Moreover, ANB has a history of promoting participatory approaches to green space management (Van Herzele *et al* 2005). In the *Green in the City* project, ANB addresses voluntary engagement and stimulates local authorities to adapt their planning and management traditions and arrangements regarding environmental and biodiversity issues in cities. Every year ANB issues a call for projects that involve experimental and innovative actions for a specific theme. Such efforts support interested city authorities in designing greener cities and also involve local inhabitants; however, to date they do not have much experience in providing information on any specific health related aspects. The ambition of ANB to mainstream knowledge on the advantages of urban green space and greenery is positive and may inspire local institutions and actors, but this will not necessarily strengthen the link between biodiversity, human health and well-being, nor turn general concepts into effective measures and models for healthy town development. Nevertheless, basic data and knowledge regarding green space and health are being developed for Belgian cities (Van Herzele *et al* 2004, Van Herzele and de Vries 2012), in keeping with the development of general knowledge regarding contact with nature and health (Hartig *et al* 2011). It seems, however, that the *Green in the city* strategic project has yet to take advantage of this knowledge, and integrated programmes to ameliorate public health problems through intelligent application of green space and biodiversity remain to be developed.

The second example here involves a series of urban sustainability initiatives started several years ago by the Brussels Capital Region, in collaboration with local organizations (appendix B). In addition to the role of urban biodiversity as being a natural corridor of biodiversity between neighbour regions, the importance of urban green space and biodiversity for physical and mental health is emphasized in these initiatives, as are other links between ecosystem health, biodiversity, food security, human health and the impact of citizen behaviour on environmental, social and economic issues elsewhere in the world. Most of these regional initiatives benefit from funding from the Capital Region. However, the funds are too limited to fully address the growing demand of citizens to participate in such projects. As a result, these activities are largely based on the goodwill of some motivated citizens, and they often lack scientific and technical support and expertise (e.g. regarding potential effects on emergent diseases). These initiatives nonetheless contribute to urban social health through new collaborations between different urban districts, the exchange of experience among inhabitants, and renewed appreciation of traditional knowledge.

2.3. Lessons and challenges

The example of foxes in Flanders shows that an increasingly urbanized wild animal may bring with it the potential risk of infectious diseases as well as the potential to reduce the risk of other infectious diseases. The example also shows that developments in neighbouring countries need not occur the same way; local circumstances may differ substantially. This means that detailed, location-specific knowledge needs to be carefully monitored to help avoid outbreaks of diseases. Moreover, the complexity of the ecological associations between parasite, definitive host (canids and certain wild mammals), secondary hosts (rodents) and 'accidental' hosts (humans and domestic animals), and the interplay with land use planning and environmental health issues, illustrates the importance of integrated approaches.

The case of the mosquitoes and the avian flu also show that biodiversity can play different roles in public health. While an increase in diversity of mosquitoes also increases the range of diseases potentially transmitted in Belgium, the lack of diversity in commercial poultry production contributes to the emergence of dangerous pathogens. Whilst associations between European wild biodiversity and disease risk in West Nile virus are largely unknown, it is clear that risks of highly pathogenic avian influenza are closely associated with the movements of migratory species, the status of ecosystems they depend upon and their proximity to human settlement. Linard *et al* (2007) illustrate that in order to understand the spatial variation in disease risk of vector-borne and zoonotic diseases in Belgium, both environmental and socio-economic factors need to be taken into account, thus requiring an integrated interdisciplinary approach.

The urban green space examples illustrate renewed attention to the benefits of nature in the urban context, complementing the sanitary–environmental and the techno-economic models that have been dominant in shaping urban public health over the last decades (Rayner and Lang 2012). The changing role of the authorities becomes apparent; giving incentives and providing examples of good practice seem to be the favourite strategy, while imposing or working according to a prescribed and comprehensive plan receives less attention. Time will tell if efforts to inspire a diversity of actors—not only by sharing information but also by sharing responsibility through new, more collaborative, governance arrangements—will yield durable improvements in biodiversity and human health. Here also the need for integrated approaches is evident, for among other things taking both ecosystem services and potential disservices into account.

The different examples together show the need for integrated approaches to landscape planning that respect the links among urban and periurban areas. The overarching challenge is to plan public and private green spaces in densely populated regions in such a way that they are sufficiently diverse and accessible to humans and yet do not create conditions that will lead to the proliferation of hosts or vectors of diseases. This requires more background knowledge and access to information than is currently available to city planners. The fact that private green spaces also play a role points to the need of better informing the public and structurally supporting public–private collaborative arrangements.

3. The emerging biodiversity–public health community of practice in Belgium

The foregoing examples have shown that an integrated approach is needed both to address each of the issues separately but particularly when developing green space in urban areas so as to ensure increase of ecosystem services without creating or increasing potential health risks. An analysis of the current research landscape (appendix C) quickly revealed that there is little research on biodiversity and public health in Belgium so far. Moreover different policy communities who do not usually come together in their work (health and planning) need to be brought together—by increasing the evidence base on health-biodiversity linkages in Belgium, by building communication networks across disciplines, and by devising frameworks for on-going collaboration and practical action.

Against this background and to raise awareness in Belgium on the importance of the linkages between biodiversity and public health, on 30 November 2011 the Belgian Biodiversity Platform organized the first Belgian Biodiversity and Public Health Conference 2011 (see www.biodiversity.be/health). This conference, its outputs and subsequent developments stand as constructive examples of efforts to address issues at the biodiversity–public health–urbanization interface.

3.1. The initial gathering: bringing different communities together

The Belgian Biodiversity Platform encourages interdisciplinary co-operation among scientists and serves as an interface between researchers and policy makers. The conference it organized in 2011 consisted of introductory keynote speeches and five thematic workshops. The conference brought together eighty one Belgian experts. Roughly 68% of them were scientists (universities and governmental scientific institutes; health-, ecological- and social-science), 16% represented policy interests (Federal, regions, provinces, cities; health-, environmental-, nature- and land-planning policy), and 16% came from consultancies (policy advice, eco-therapy, education), NGOs (nature protection, landscape development, ecological life and gardening, health insurance), or media.

Discussions during the conference focused on scientific priorities and policy challenges and resulted in the identification of several issues of interest. The *Infectious Diseases Workshop* identified the following priority issues: (1) The need for biodiversity-related research on, for example, the distribution and abundance of reservoir and host species, the influence of host diversity on disease transmission, the diversity of pathogens and their geographical distribution patterns, and how the diversity of resources (e.g. food) influences epidemiological cycles. (2) The need for more collaboration amongst Belgian research teams and between different policy fields, such as landscape management authorities and public health agencies. (3) Disease Early Warning Systems. (4) Eradication of invasive species.

The *Food Workshop* listed research priorities such as genetic diversity, health related diversification of diet, multifunctional agriculture, the 'real' price of food (including social, environmental and other costs), and ways to incorporate this knowledge into policy instruments. Raising awareness among consumers and catering chains, the relationship between social diversity and use of biodiversity, and the potential of urban biodiversity (allotments, gardens) for local food production were addressed as important social/policy challenges.

The *Nature Experience Workshop* underlined the importance of involving different policy domains (agriculture, nature, public health, education, spatial planning, and mobility) to bring scientific insight closer to practice. In this respect the challenge of fine tuning the generic policy level to context specific needs was specifically underlined. For example, generic policy (and the research which supports such policy) addresses broad environmental categories (notably natural and urban), and so does not provide adequate support for the kind of specific design interventions that can reconcile increasing urban population density with the values of contact with nature (Van den Berg *et al* 2007).

The *Spatial Tools Workshop* highlighted data-related issues such as open data access and data integration. The importance and difficulty of scale coordination was addressed (e.g. reconciling factors at different policy, geographic and temporal scales). Also, the importance of communication and collaboration among a diversity of experts from science, policy and society was underlined. It was stressed that the links between biodiversity and health in the landscape context are often vague or uncertain and in need of further research, and that spatial planning tools such as ecosystem service mapping can be important in this regard.

The *Ecosystem Services Workshop* generally considered the ecosystem services concept an opportunity to strengthen linkages between public health and biodiversity. To take this forward, preliminary steps were suggested, including (1) development of a catalogue of linkages between biodiversity and public health; (2) development of an overview of existing data and indicators; and (3) reinforcement of communication and collaboration among thematic experts and policy representatives.

3.2. Next steps: movement towards a Belgian community of practice on biodiversity and public health

One generic outcome of the conference was recognition of the need for further capacity and network building. On the one hand this implies a focus on generating further scientific understanding in order to be able to provide policy makers with robust knowledge. According to some participants this is the prime challenge:

> This obviously was a first attempt at bringing together science and policy making. Much more effort will be needed to achieve long term results. At this stage focus should be on getting scientists to agree on the link between biodiversity and public health. This was still very unclear at this stage, and it may have confused decision makers (Keune *et al* 2012a).

Others stressed that this was not only a scientific challenge, but also a practical challenge, or as one participant put it:

> Involve more people from a diversity of contexts to give presentations, not only scientists. Otherwise you risk inward looking in academic circles, when the outside world (reality) is not always in accordance with scientific findings. The biodiverse system of humans and nature is more than the sum of the parts, but instead is an interactive interplay of many actors, not only scientific research. My main message is: invite more people from many contexts who are dedicated to biodiversity, it is only then you can reach an integrated full picture. A challenging opportunity (Keune *et al* 2012a).

Shortly after the conference, a policy brief was issued in which science, policy, and other experts called for support for the establishment of a Belgian *Community of Practice on Biodiversity and Public Health* (Bauler *et al* 2012). A *Community of Practice* (CoP) is a network made up of individuals and organizations that share an interest and practice, who come together to address a specific challenge, and who further each other's goals and objectives in the specific topic area (Wenger and Snyder 2000, Meessen *et al* 2011). Inspiring international examples are the Canadian Community of Practice in Ecosystem Approaches to Health (COPEH) and the European Community of Practice in Farming for Health (Dessein 2008). These examples of Communities of Practice show how different expert communities can connect by networking and capacity building and hence contribute to more integrated approaches.

3.3. Further development: creating an inventory of research needs

In 2012 the emerging *Belgian Community of Practice on Biodiversity and Public Health* decided to organize an inventory of research needs and ideas in order to get a clearer view of relevant research topics and the potential for collaboration (Keune *et al* 2012b).

The policy-driven research needs, articulated by diverse policy representatives (both national and regional), cover a wide range of topics and policy-relevant issues. There is a general interest in integrated data assessment that couples ecological and public health developments, as well as a general interest in the relations among green space/nature, the living environment, and public health. Some specific research topics involve health risks or health benefits, or both. More specific thematic focuses include links between biodiversity and dietary health, medicines and medical research, and emerging disease threats. Regarding the connections between green space and public health, specific topics include the social, mental and physical health benefits of green space and other contact with nature, their accessibility for residents, and the relation between ecosystem services and non-communicable disease such as cancer and diabetes.

Research input has come from members of national, Wallonian and Flemish research institutions representing a wide range of expertise. Some of the research gaps identified included a need for further work on vector-borne diseases, including patterns and mechanisms of emerging infectious diseases in domestic animals, further development of surveillance and monitoring systems, the influence of habitat and ecosystem change on pathogen ecology, the role of land use management in vector control, and expanding knowledge of the virome (the genomes within a viral population existing in a given organism, a given population or a given ecosystem) and its link with biodiversity and public health. Several proposals draw attention to ecosystem health services, for example in relation to a diversity of habitats, landscape and species, urban greening and the demand for ecosystem services and biodiversity.

The diversity of the proposals and of the scientific and policy backgrounds and institutions involved illustrate an emerging community of expertise and practice with both the potential and the will to join forces and build capacity. As one policy representative put it: 'We found this exercise of gathering ideas very interesting for the community of stakeholders and it was a good opportunity for ourselves to lay bridges between dossiers inside our own service'.

4. Conclusions

The challenges for research and policy on the issues of biodiversity and human health in the context of urbanization are substantial. The first Belgian Biodiversity and Public Health conference discussed many of the barriers to mainstreaming ecosystem approaches to human health, and identified some key areas for action. Firstly the evidence base on links between biodiversity and health in the context of urbanization must be further developed so that areas of overlap between various fields of research, policy and practice can be better identified. More research is needed to facilitate a better understanding of the connections, and to support informed decision making and long term assessment and monitoring. Secondly, bridges must be built between different professional communities working within the biodiversity-health-urban planning sphere, and at all levels of policy, research and practice. At the Belgian conference there was some notable friction between different scientific and policy perspectives of the role of biodiversity and ecosystems, to public health and more widely. The *ecosystem services community* mainly highlighted the benefits of biodiversity to human health, whereas the *infectious disease community* to a large extent focused on the public health risks of human contact with nature. Both communities in a sense focus on the same human–nature interactions, but from different perspectives based on different methodologies, different realms of knowledge, widely divergent scales of operation and different practical objectives. To some extent, the problem is perhaps one of semantics ('nature' and 'biodiversity' do not necessarily equate), compounded by a lack of clearly established definitions of core concepts (for example, a negative outcome of human interaction with nature may be attributable to certain aspects of 'wildlife' but may not necessarily be a factor of 'biological diversity') and a lack of understanding on each side of one another's key drivers (both in the policy and practical sense). Some of this difficulty may perhaps be resolved by a more coherent working definition for this kind of forum of what is meant by biodiversity and ecosystem services, and by development of a working conceptual model for Belgium that will facilitate interdisciplinary and ultimately transdisciplinary approaches. Such models may also benefit from a broader definition of health, incorporating 'the ability to adapt' and recognizing the value of health as an indicator of sustainability, which promotes overlap with many aspects of the ecological sciences and can serve to highlight areas of mutual concern. In addition, it is important to look beyond ecology and public health disciplines to ensure that the many other disciplines affected by these issues are also closely involved, including forestry, agriculture, fisheries management, economic and social development, and so on. Thirdly, there is a need for a practical framework for on-going communication and collaboration, to enable exchange of ideas and experience and to support capacity building. And finally there is the need for better communication of the science of biodiversity and health linkages to policy makers, and to the general public.

The *Belgian Community of Practice on Biodiversity and Public Health* recognizes these challenges and is currently working to support further collaboration and capacity building to tackle these important sustainability challenges. In this way the Belgian community also hopes to contribute to the international body of knowledge and practice, such as the IPBES and other relevant processes.

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Appendix A. Belgian governmental policy landscape

The Belgian governmental policy landscape is quite complicated due to its specific federal structure, in which the federal level, the regional level and the community level play a role regarding biodiversity (Belgium's National Biodiversity Strategy 2006–2016) and public health issues (National Environmental Action Plan). In Belgium the three regions (Flanders, Wallonia and Brussels) are responsible for all territorial matters, including most biodiversity-related matters and land use planning. The regions are also responsible for the larger part of health policies, including health prevention. At the federal level health policies mainly deal with animal health and food safety. The three communities (French, Flemish and German) deal with cultural matters including culture and media, education, use of languages, some aspects of health policy, youth protection and sport. Certain collaborative and coordinating institutional structures exist, in which representatives of the different federal, regional and community policy level meet, in order to streamline the Belgian position regarding international forums and policies and to vice versa establish a coordinated implementation by Belgium of the decisions and recommendations made in international forums, such as e.g. European Union policies, the National Environmental Action Plan initiative of the World Health Organization, the Convention on Biological Diversity or the recently established Intergovernmental Platform on Biodiversity and Ecosystem Services. Still, apart from the challenge of interfacing different policy fields such as biodiversity and public health, also the federal structure of Belgium imposes quite a challenge on fine tuning. To further explain the historical roots of this fragmented governmental landscape is beyond the aim of this letter, but it is a complicating reality to be taken into account when dealing with a combined focus on biodiversity, public health and urbanization.

Appendix B. City green spaces initiatives in Brussels

For several years, the Brussels Capital Region has run a series of initiatives, in collaboration with several local organizations (Centre d' Ecologie Urbaine, le Début des Haricots, Apis Bruoc Sella, Tournesol, Etopia, GASAP and others), exploring various aspects of urban sustainability. Several of these projects seek to promote sustainable development through educational and collaborative local projects for greening public spaces (www.villedurable.be/thema/ville-verte), create urban collective vegetable gardens (including on green roofs of large buildings) (www.potagersurbains.be) and orchards (www.gasap.be/des-vergers-collectifs-a-bruxelles), placing beehives in the city (www.apisbruocsella.be), promoting sustainable food (www.rabad.be), developing Sustainable Districts ('Quartiers durables') where local motivated citizens organize activities to increase awareness within their neighbourhood on issues linked to sustainability, and to encourage local projects to enhance urban spaces by tackling litter and improving biodiversity (www.bruxellesenvironnement.be/templates/particuliers/niveau2aspx?id=3204).

Some of these projects, like 'Maillage vert' (Green Network), emphasize the potential obstacles which urban spaces present to the passage of biodiversity and the movement or flow of ecosystem services through the wider landscape, and aim to develop a green infrastructure that addresses this concept and provides wider benefits. Targeted local actions include removing or avoiding exotic and potentially invasive species or varieties of flora in favour of indigenous plants, and encouraging use of native tree species in urban planting. In all these projects, the value of urban green space and biodiversity for physical and mental health is also underlined, as well as the links between biodiversity and ecosystem health, food production and nutrition security etc (e.g. the Apis Bruoc Sella project shows pollinators as indicators of ecosystem health and as examples of important ecosystem benefits which urban greenspace can provide) as well as highlighting the positive or negative potential impacts which local citizen behaviours may have on environmental, social and economic issues elsewhere in the world. For example, the development of urban community vegetable gardens is seen as a means of reducing the impacts of community choices on ecosystems in other areas, encouraging a degree of self-sufficiency and promoting healthy and diverse food production whilst also promoting outdoor recreation, social interaction and community cohesion.

Importantly, most of these regional initiatives benefit from some funds of the Region, but that are still rather limited for the growing demand of the citizens to participate in such projects. As a result, these activities are largely based on the good will of some motivated citizens, but they also often suffer from lack of expert scientific and technical data and support. Several of these urban projects are examples of 'learning by doing', experimenting and adjusting management practice based on experience and knowledge gained along the way. Whereas this could somehow be considered as risky, it is also fostering a new kind of collaboration between distant urban districts inhabitants exchanging experience and revisiting traditional knowledge, improving by this way the urban social health.

Appendix C. Project database screening

Research projects focusing on the link between biodiversity/ecosystems, human/public health and urbanization are fairly rare in Belgium. To illustrate this, we screened five databases collectively holding project information from the Federal Authorities, Flemish Community and Francophone Community for the past 12 years. When classifying each of the 45 public health related research projects according to their major research focus, the large majority seems to target the effects of environmental hazards (such as water and air pollution) on human health, exemplifying the sanity–environmental approach (Rayner and Lang 2012) in Belgian research policy. Projects studying the link between biodiversity/ecosystem related issues and public health, on the other hand, are clearly less common and of these, only a very small number (5) also target urban issues. They are all funded by federal funding sources, and three of these started in 2009 illustrating increasing interest in this topic from 2006 onwards. Studies focusing on biodiversity/ecological aspects of human/public health in Belgian urbanized areas are still in their infancy; in the Walloon region, they are even completely absent.

We screened five databases collectively holding project information from the Federal Authorities, Flemish Community and French Community with focus on the past 12 years. These include the INVENT database (from the Belgian Science Policy office), the Flemish Research Information Space (FRIS), the database from the Research Foundation Flanders (FWO-Flanders), Vision on Technology (VITO), and

Table C.1. Number of public-funded research projects in Belgium on the link between biodiversity/ecosystems, human/public health and urbanization (1998–2011).

	FL	FR	FE	1998[a]	2000	2001	2002–2005	2006	2007	2008	2009	2010	2011	Total
Biodiversity and public health		1	4					1	1		3			5
Biodiversity and public health and urbanization		1	4					1	1		3			5
Environmental hazards and public health	15	3	19	1	1	1		6	7	6	10	5		37
Environmental hazards and public health and urbanization	7	2	11		1	1		4	5	4	4	1		20
Urbanization and public health	7	3	17		1	1		5	7	4	8	1		27
Biodiversity and environmental hazards and public health		1	4	1				2		2				5

[a] Year a project started.

Agency for Nature and Forest (ANB). In order to select from these a list of research projects focusing on public health in Belgium, we used several keywords (biodiversity, ecosystem, urban, city, environment, health) and several combinations thereof. Abstracts were carefully screened to exclude studies on ecosystem or animal health (if no link with public health), and studies targeting regions outside Belgium were also excluded. This resulted in a unique list of 45 public health related research projects (table C.1), the majority of which were funded by the Federal Authority (FE: 24 projects); projects funded by the Flemish (NL) and French (FR) community were less common (17 and 4, respectively). The projects were subsequently classified into six groups according to their major research focus. Some of the categories had a broader focus than others, and as a consequence projects often classified in more than one group. Within each category, the start date of each project was indicated to decipher trends in timing of funding. Project databases from the Walloon region were not accessible, but given that the screening of Flemish databases outside INVENT revealed only three additional projects, we are confident that the recovered trends are representative for the post-2000 period.

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