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Bringing health and the environment into decision making: A natural capital framework

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Executive Summary

The aim of this paper is to present a concise overview of the variety of measures, or 'metrics', available for understanding the consequences of change in the environment. That change might be driven either by natural causes or, as is more frequently the case, as a result of human decisions and behaviour.

This paper is primarily provided as a briefing to The Rockefeller Foundation Economic Council on Planetary Health. Given the emphasis upon human health within the remit of the Council, we open with a review of metrics of human health and wellbeing. From an initial focus on the assessment of physical health status, the discussion expands to consider mental health and wider measures of wellbeing.

The paper then expands to consider metrics for environmental status including both quantity and quality measures. This highlights the great diversity of measures associated with change in the environment and the problem of assessing and comparing such metrics.

These reviews highlight the challenges of trying to make better personal, policy and business decisions in a complex world where changes to the environment (including the urban, rural, work and home environment) have multiple effects. For example, any change to, say, our use of land can simultaneously effect economic production, food outputs, the quality of water and the air, the climate, risks of natural hazards like flooding, opportunities for healthy recreation, habitats for other species and numerous other issues. This is because the environment is an interconnected system where a change to one part can have multiple consequences to other connected parts of that system. Failing to recognise these wider effect and their negative trade-offs and positive synergies would result in poor decisions; literally we would only be looking at a sub-set of the effects of change. Unfortunately such incomplete assessment is commonplace.

Given the inevitability of trade-offs and synergies, following the reviews of health and environmental metrics, the paper moves to consider how the wider effects of environmental change can be incorporated within decision making, and in particular the economic analyses which underpin most decisions. This is vital because a sole focus upon health metrics, however broad, risks the pigeonholing of the remit of the Council's work to a subset of decisions which are already about health issues. In effect such an analysis would dissolve down to arguments about how to allocate a pre-determined budget (i.e. the real decisions about whether to focus on health or other issues having already been made). In order to influence a wider set of business and policy investments, the health and environment impacts of change have to be mainstreamed into wider decision making. This will not work in a single direction; on some occasions the trade-offs between investing in health and investing in other areas will not favour the former; for example in cases where health interventions are relatively ineffective. However, given that most decisions fail to consider health and environmental impacts, mainstreaming these effects into decisions should, as a whole reallocate, resources efficiently towards delivering improvements in these areas.

We present a conceptual framework for bringing these issues together and mainstreaming the health and environment impacts of change into wider decision making. Key to this is to ensure that the wider impacts

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of change are considered within decisions. As part of this discussion we consider how all of the effects of investments, including their trade-offs and synergies, can be compared with each other in a commensurate manner. Here we consider arguments for and against the use of economic values as a way of ensuring this commensurability and overview advances in techniques for providing such values.

The paper concludes by considering the potential for adopting these metrics and the wider framework as a means of positioning human health within efforts to deliver environmental sustainability as well as more general real world decision making.

1. Health Metrics

1.1 Introduction

A wide range of existing global human health metrics are related to environmental sustainability. Many of these are already captured in a range of tools, frameworks and datasets produced by global bodies. Some key frameworks are summarised here, followed by a brief description of common population health metrics in use. The remainder of this section is devoted to discussion of the opportunity to take a balanced approach to consideration of health metrics in the context of environmental sustainability, recognising the complex interdependencies that underpin the Planetary Health approach. It also highlights that much of what is currently measured regards disease and injury, rather than health and wellbeing, and the opportunity to recognise the role of the environment in promoting good health and wellbeing in order to rectify this imbalance.

1.2 Existing Frameworks & Indicator Sets

One of the most important collections of global health metrics is that produced by the World Health Organisation (WHO) Global Burden of Disease (GBD) Project.[4] This reflects a general focus on measures of 'disease' as opposed to 'health', which is discussed further below. The GBD uses national and international data sources to measure a very wide range of population disease and injury outcomes, including rates of communicable and non-communicable diseases, mortality, along with health-related behaviours, and risk factors. Work specifically on the burden of disease from environmental risks estimates that 23% of global deaths each year are related to environmental causes (with a broad definition of 'environmental').[5] These impacts include, for example, an estimated 2.8m deaths per year due to non-communicable diseases associated with outdoor air pollution, c.370,000 deaths due to drowning, and over half a million deaths due to malaria (Prüss-Üstün et al. 2016).

More specifically the WHO produces a Global Reference List of 100 Core Health Indicators, intended to concisely summarise global priority health measures.[6] These are not explicitly framed as environment-related health measures, but a number of the indicators are relevant here, such as the mortality rate from road traffic injuries or the air pollution level in cities. Others are more indirectly environment-related, such as *"Insufficient physical activity in adults"* (discussed in 1.4).

Work has also been carried out to link health outcomes in the GBD to the Sustainable Development Goals (Fullman et al. 2017). Along with an overall goal specifically on "Good Health and Wellbeing" (Goal 3), the Sustainable Development Goals include a large number of health indicators, from natural disaster mortality to overweight prevalence in children aged under 5 years (see Annex 1).

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[4] http://www.who.int/topics/global_burden_of_disease/en/
[5] http://www.who.int/quantifying_ehimpacts/publications/preventing-disease/en/
[6] http://www.who.int/healthinfo/indicators/2015/en/

Many other organisations compile global indicator sets including health measures from a variety of sources (often including WHO GBD), such as the World Bank[7] and the UN Human Development Programme.[8] Amongst more environmentally-focussed programmes, the Yale Environmental Performance Index[9] captures a range of environmental sustainability indicators, such as nitrogen use efficiency, or the state of fish stocks, but also includes five indicators on environmental risk exposures presenting a direct human health hazard. These are unsafe water, unsafe sanitation, household (indoor) air pollution from solid fuels, ambient (outdoor) particulate matter, and ambient ozone pollution. However, these indicators are in turn drawn from the WHO GBD, the source for much comparative global health data.

In summary, the Global Burden of Disease and other collections of health metrics with relevance to the environment generally focus wholly, or largely, on environmental hazards and consequent disease, injury and mortality – not health or wellbeing. This traditional focus views the environment primarily as a set of hazards that present a direct or indirect human health risk. This approach positions health in environmental sustainability in terms of how we may mitigate population disease/injury risks through hazard reduction and health protection measures. Following a brief description of some of the key types of health metrics available, this issue is explored more substantively in section *1.4*.

1.3 Metrics

The simplest forms of health metrics are those capturing some form of population measure of disease, injury, death or disability. These may be measures of *prevalent* (current) cases, such as the proportion of a population currently diagnosed with Type 2 Diabetes, or *incident* (new) cases over a specified period of time, such as the rate of new cases of malaria per 1000 population per year. *Mortality rates* capture the 'incidence' of death, often sub-divided by cause of death. Mortality rates may also be translated into *life expectancy* (a summary measure of current mortality, rather than an actual prediction of the length of life of individuals). Prevalence and incidence measures are often age/sex-standardised to account for the substantial effect of demographics on population health measures. Similar metrics to those for health outcomes can be used to indicate the prevalence or incidence of health risks or behaviours, such as the proportion of the population currently meeting guideline levels of physical activity.

The *Population Attributable Fraction* (PAF) is used to allocate a proportion of the cases of a disease or deaths to a particular risk factor. This measure indicates the proportion of cases that would not occur if the risk factor were reduced to an idealised scenario (not necessarily zero). For example, the WHO GBD estimates the PAF for diarrhoeal diseases associated with inadequate drinking water to be 34%.

A variety of measures use prevalence/incidence rates alongside other data or models to estimate the economic cost or value of disease, mortality, health states or behaviours. These measures can portray direct healthcare costs related to treatment and management of a condition (e.g. estimated at Intl$825 billion per year for diabetes (Non-Communicable Disease Risk Factor Collaboration 2016)). Economic valuation can also be applied to estimate the total societal *cost-of-illness*, additionally taking into account lost productivity, loss of years of life through premature mortality and loss of quality of life.

The WHO GBD project uses one of the primary measures of cost-of-illness, in calculating *Disability Adjusted Life Years (DALYs)* as a key metric alongside raw mortality rates. DALYs reflect both years of life lost due to mortality, and years lost due to disability or disease. A similar measure, the *Quality Adjusted Life Year (QALY)* is also used in health economic studies, often to value the effects of interventions, where 1 QALY gained is one additional year lived in 'full health' by one person. Both measures require weights, which adjust the value of time lived with illness or disability such that a year lived with a certain condition or in a specific health state is worth a specified proportion of a year lived without illness or disability. They may also weight the value of a year of healthy life differently at different ages. These weights are derived through a variety of

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[7] http://datatopics.worldbank.org/health/home
[8] http://hdr.undp.org/en/data
[9] http://epi.yale.edu

methods, and future gains/losses of healthy years of life can also be subject to discounting (where current health is valued more highly than future health).

Given the processes of weighting the value of life spent in different circumstances, discount rates and so on, these 'cost-of-illness' measures are subject to debate, and have also been critiqued in terms of being insensitive to inequality (Whitehead and Ali 2010, Arnesen and Nord 1999, Williams 1999). However, the measures do have some advantages, especially when health gains are to be offset against the costs of, for example, environmental intervention. This issue of the importance of commensurability of measures for considering health and the environment is discussed in Section 3.

1.4 Promoting a balanced approach

An important and often-quoted definition of health, from the establishment of the World Health Organisation in 1948 is:

> *"Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"* (WHO 1948)

Since 1948, numerous suggestions for update and augmentation of the definition have been made. In defining *Health Promotion*, the 1986 Ottawa Charter stated that:

> *"To reach a state of complete physical, mental and social well-being, an individual or group must be able to identify and to realize aspirations, to satisfy needs, and to change or cope with the environment. Health is, therefore, seen as a resource for everyday life, not the objective of living."* (WHO 1986)

More recently, an alternative definition has proposed health to be *"the ability to adapt and to self-manage"* (Huber et al. 2011).

These definitions are helpful in considering how human health metrics situate within environmental sustainability. Positioning human health outcomes in environmental hazard contexts – air pollution, water quality, communicable disease and so on - is extremely important, as is consideration of how future environmental change is likely to impact upon hazards and the health outcomes concerned. However, it is clear that most health metrics are actually currently 'disease metrics'; considerations of the global population health impacts of environmental conditions generally have a narrow, hazard-risk-disease/mortality focus, and do not even properly reflect the breadth of the original 1948 definition.

A more balanced view would consider human health and environmental health as mutually dependent; the essence of Planetary Health. Alongside the significant direct risks to health from environmental conditions, we can consider more indirect relationships, the opportunities for health *and wellbeing* that our environments present, and issues of social, environmental and intergenerational equity. Importantly, we can also explicitly consider how our health-related outcomes and activities can have deleterious – or beneficial - environmental impacts themselves. These interconnecting, cyclical relationships are depicted figuratively in **Figure 1**.

The figure highlights that interconnections also exist between environmental and health-related policies, and that pro-environmental policies/behaviours can directly impact human health, and improve environmental conditions, also indirectly benefitting health. For example, policies supporting increased active travel (especially walking or cycling) have the potential for multiple benefits to the health of humans and the environment, including reduced carbon emissions, improved urban air quality (with consequent positive health impacts), and promotion of everyday regular physical activity amongst an increasingly sedentary global population (de Nazelle et al. 2011). Conversely, health promoting policies may have deleterious impacts on the environment, with direct and indirect impacts on human health. For instance, increased prescribing associated with ageing populations and improved healthcare systems can lead to the release of pharmaceuticals and their metabolites into sewerage systems, with consequences for wildlife, ecosystems and humans (Depledge 2011).

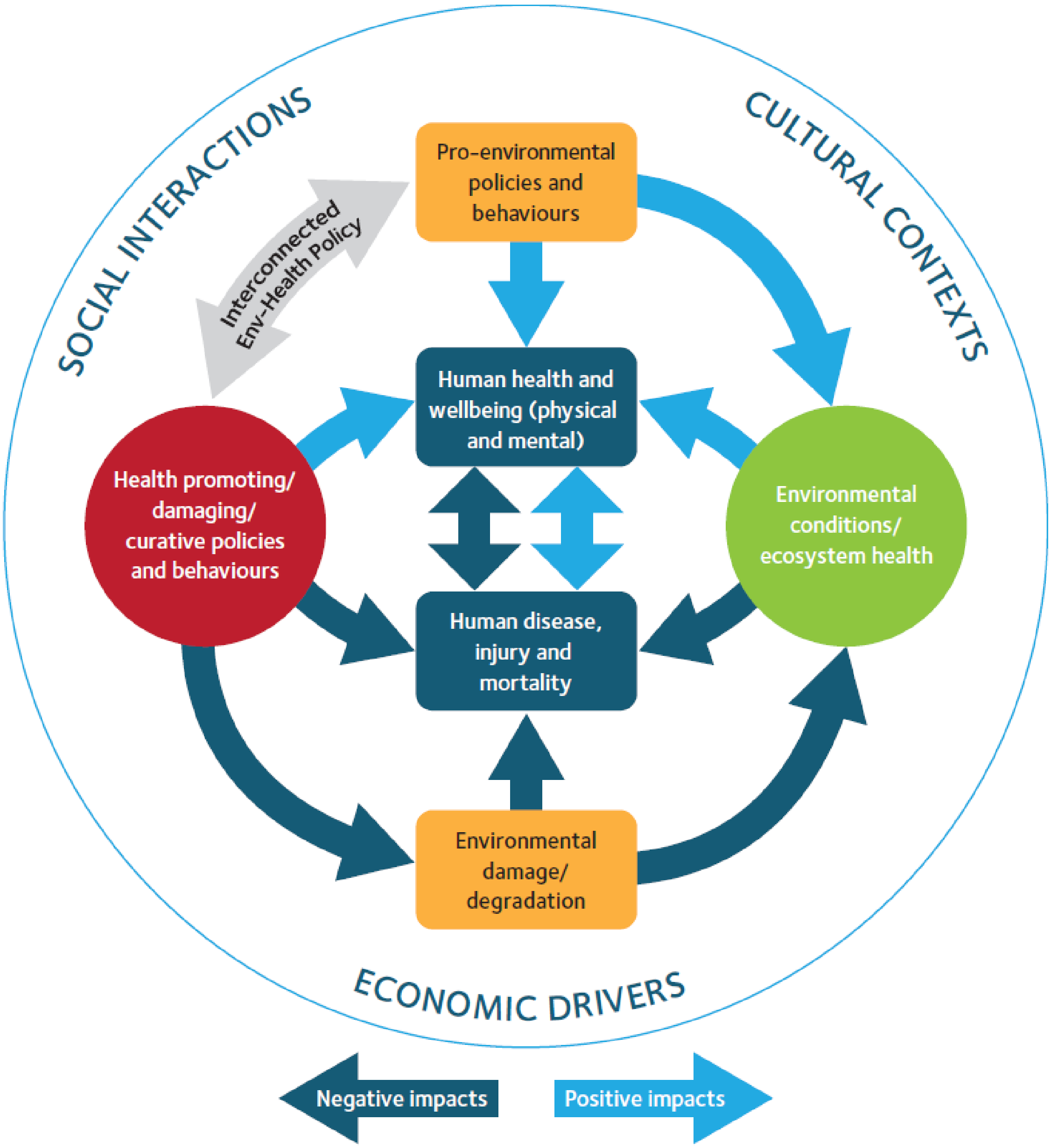

Figure 1. Interconnections between environments and human health

Whilst these concepts are not entirely novel (having been raised in concepts such as 'Ecohealth' and 'OneHealth'), the era of Planetary Health recognises the importance of this complex interdependence. Work on climate change and population health has highlighted that many of the actions for mitigation or adaptation can actually have health (and other) *co-benefits* (Watts et al. 2017).

Taking a broad view of health, such as that of the Ottawa Charter (WHO 1986), or the more resilience-focused 2011 definition (Huber et al. 2011), there is a clear opportunity to consider more holistically the interconnections between environmental sustainability and human health. Reflecting these wider definitions of human health, there is scope to consider the value of *good environmental conditions for human health,* and the environment as a promoter of health and wellbeing, as well as merely considering environmental risks and processes to ameliorate environmental hazards.

The global evidence base is increasingly indicating the positive value of good quality environments – both natural and built - for the health and wellbeing of the population (Hartig et al. 2014, Grellier et al. 2017, Jackson, Dannenberg, and Frumkin 2013). With a rapidly urbanising planet, there is a significant opportunity to situate health and wellbeing metrics for relevant outcomes within the context of the form and character of existing and developing urban areas. Relevant metrics here could include, for example, mental health and wellbeing-related outcomes associated with natural environments, and the environmental determinants of health-promoting physical activity, such as walkable cities. Figure 1 emphasises the importance of not considering environment-health interconnections in isolation, but in a complex context of social interaction, cultural context, and economic drivers of the underlying processes. A good example here is the interaction between positive health impacts of good quality urban environments and socio-economic inequalities. There are suggestions that good quality living environments may be 'equigenic' – that is, equality-promoting – lending some degree of resilience to the health damaging impacts of socio-economic inequality (Mitchell et al. 2015, Wheeler et al. 2015). However, it is also possible that urban environmental improvement (such as 'urban greening') could have unintended consequences of gentrification and socio-economic segregation, and this warrants consideration and monitoring (Cole et al. 2017).

Whilst the concept of wellbeing is broad and conceived of in many ways, there are now internationally standard metrics for measurement of population subjective wellbeing (quality of life, happiness, anxiety and life satisfaction). These have been robustly developed to reflect the economic literature on subjective wellbeing (Dolan, Peasgood, and White 2008), and have been adopted by the OECD (OECD 2013). In turn, research has indicated the potential importance of good quality environments to promote subjective wellbeing as captured by these metrics (White et al. 2017).

Finally, the issues of multiple environmental exposures and multiple vulnerabilities, which may have antagonistic or complementary health impacts, need to be considered. 'Exposome' approaches (Wild 2012) typically consider the combined health impacts of exposure to multiple chemical pollutants, and may also incorporate exposures to other hazards such as noise and temperature extremes. We need to recognise and allow for the fact that environmental conditions may have both positive and adverse health impacts, which may be synergistic or antagonistic. For example, management of urban parks for biodiversity may improve their value as a resource for rest, relaxation and physical activity, but may simultaneously increase exposure to allergenic pollen and vector-borne diseases.

Individuals and populations may have multiple vulnerabilities, including existing poor health, and experience inequalities of gender, ethnicity, race, income and so on. These vulnerabilities in combination with multiple environmental exposures make for complex webs of health-environment interconnections and feedback loops. Whilst it is challenging for health metrics to thoroughly capture this complexity, it should at least be acknowledged. Continuing to primarily position health in the context of environmental hazards itself risks over-simplifying this complexity, and missing an opportunity for a more comprehensive positioning of environment-health interconnections.

Table 1 indicates an exemplar compendium of the types of metrics that could start to reflect this more balanced view of health and wellbeing in the context of environmental sustainability. The table includes both more traditional disease and risk indicators (as currently measured) and wider health, wellbeing and health-related environment indicators. This latter part of the table is a somewhat aspirational selection, as many do not have globally available, consistently measured data to underpin them. Reflecting the discussion above, there are some areas for which metrics are nascent – such as the WHO urban greenspace indicator (WHO 2016). This indicator measures the proportion of the urban population living within 300m of a green space of minimum size 0.5ha. Other measures that may be challenging to produce, but are still worthy of consideration and development, such as the quantity of biologically active pharmaceuticals and metabolites entering fluvial and marine systems. Note that the final rows of Table 3 also consider a further metric; the translation of improvements in health into economic value measures.

Table 1: A Compendium of Health Metrics

Indicator	Outcome	Potential data sources	Metric	Sources
Exemplar Disease & Risk Indicators				
Lower respiratory infections associated with ambient and household air pollution	Morbidity & mortality	WHO Global Burden of Disease	Disability Adjusted Life Years (DALYs) (relates to SDG 11)	(Prüss-Üstün et al. 2016, SDSN 2015)
Malaria incidence	Morbidity & mortality	WHO Global Burden of Disease	DALYs, mortality rate (SDG 3 indicator)	(Prüss-Üstün et al. 2016, SDSN 2015)
Road traffic injuries	Injury-related morbidity & mortality	WHO Global Burden of Disease	Road traffic deaths per 100,000 population (SDG 3 indicator)	(Prüss-Üstün et al. 2016, SDSN 2015)
Stroke associated with ambient and household air pollution	Morbidity & mortality	WHO Global Burden of Disease	DALYs, mortality rate (relates to SDG 11)	(Prüss-Üstün et al. 2016, SDSN 2015)
Urban heat exposure	Heat-related morbidity & mortality	Global Urban Heat Island Data Set, NASA Socioeconomic Data & Applications Center	Average summer day maximum / night minimum land surface temperatures	(CIESIN - Columbia University 2013)
Sanitation coverage	Morbidity & mortality associated with contaminated water/sewage exposure	WHO & UNICEF Joint Monitoring Programme	% population with a safely managed sanitation service (SDG 6 indicator)	(WHO & UNICEF 2017)
Drowning	Mortality	WHO Global Burden of Disease	DALYs, mortality rate	(Prüss-Üstün et al. 2016)
Exemplar Health, Wellbeing and Health-Related Environment Indicators				
Commuting through active travel modes	Physical activity and related health outcomes; reduced urban air pollution	Censuses, population travel surveys, road traffic count surveys	% of working population commuting actively	(de Nazelle et al. 2011, Saelens and Handy 2008)
WHO greenspace availability measure	Access to green space with associated mental and physical health outcomes	Landcover maps, municipal landuse maps, population census data	% of population living within 300m of greenspace of minimum 0.5ha	(WHO 2016)
Measures of pharmaceuticals and derivatives in aquatic ecosystems	Water quality with potential ecological and human health impacts	Direct water sampling, modelling based on pharmaceutical use	Concentrations of pharmaceuticals/active metabolites in aquatic systems	(McDonald and Riemer 2008)
OECD Questions on Subjective Wellbeing	Quality of life, life satisfaction,	Social surveys	Four scales of self-rated wellbeing (each 0-10)	(Dolan and White 2007, White et al. 2017)

	happiness, anxiety			
Areas of tranquillity in urban areas	Respite from noise pollution	Noise models and mapping	Area of 'quiet areas' within a conurbation	(van Kempen et al. 2014, European Parliament 2002)
Equity of access to (or residence within) good environmental conditions	Multiple health-related environmental inequities	Requires integration of spatial socio-demographic population data and multiple health-related environmental indicators	Distributional indicators e.g. availability of greenspace within areas with highest and lowest 20% of population by socio-economic status	(Mitchell et al. 2015, Cole et al. 2017)
Value of physical activity in outdoor environments	Environmental support for physical activity and consequent health outcomes	Visit surveys	Physical activity in the outdoors → MET-minutes → QALY gains → monetary value	(White et al. 2016)
Health economic gains through positive environmental intervention	Health-related economic value of interventions with multiple impacts	Intervention-specific evaluation, models	Monetary value	(Vandermeulen et al. 2011, Lovell and Taylor 2013, Neidell, 2018)

In Section 3 we discuss the pros and cons of different health metrics, contrast these with environmental metrics and consider the challenges of bringing these into conventional approaches to decision making. As part of this we highlight the case for an economic valuation approach to assessing changes in both health and the natural environment.

2. Environmental Metrics

The literature on the measurement of environmental impacts is unevenly developed but rapidly expanding. Some of the key global environmental change threats are well understood and have mature metrics which have been assessed over considerable periods, thereby permitting the detection of trends. For example, climate change is now arguably the most intensively researched scientific phenomena globally and this is reflected in an established, peer reviewed, set of metrics. Equally importantly, climate and weather metrics have been both collected and calculated for long periods of time and different locations allowing analysts to clearly reveal changes in these metrics. These temporal and spatial data, combined with highly intensive research efforts, have allowed the projection of estimates of future climate for different parts of the world well into the future.

Table 2 builds on and updates prior work for the Rockefeller Foundation–Lancet Commission on planetary health (Whitmee et el., 2015) to provide an overview of key environmental change issues, their impacts, selected metrics for the evaluation of change and sources for those metrics.

Table 2: A compendium of environmental change metrics

Environmental change issue	Impact	Example Metrics	Sources
Climate change	Increase in temperatures, changes in rainfall patterns, changes in the frequency and duration of extreme weather events. Impacts include dislocation of agriculture and food production, impacts on water quantity and quality, direct health impacts such as heatwave stress, sea level rise and flooding, impacts on infrastructure, habitat loss and biodiversity impacts, etc.	• Atmospheric concentrations of greenhouse gases, particularly carbon dioxide (CO_2 ppm), methane (CH_4) and nitrous oxide (N_2O). • Mean global temperature change (^oC)	IPCC (2013, 2014); Sanford et al., (2014); Steffen et al., (2015).
Freshwater availability	Agriculture and food production impacts and dislocation; water poverty; migration and political tensions.	• Global water use (thousand km^3) • Population affected by water shortage (millions)	Kummu et al., (2010); UKNEA (2011); El-Zein et al., (2014); Steffen et al., (2015).
Changes in land use	Mainly from conversion of agriculture. Loss of wild species habitat and associated biodiversity, undermining agricultural resilience, dislocation of regional microclimates.	• Proportion of land used for agriculture (%)	Steffen et al., (2015).
Soil erosion and fertility loss	Threats to food production from over-intensive agricultural systems. Excessive tillage.	• Revised Universal Soil Loss Equation (RUSLE) • Soil organic carbon (mg/cm^3) • Biomass of soil functional guilds	Montgomery (2007); Lambin and Meyfroidt (2011); Mace et al., (2005); Steffen et al., (2015); USDA (2014); Zhang et al., (2017)
Nitrogen and phosphorus pollution	Supports agricultural production but generates major changes to ecosystems including nutrient pollution to waterways and marine environments	• Global fertiliser use (nitrogen, phosphorus, and potassium; thousand tonnes)	Corvalan et al., (2005); Steffen et al., (2015); Rockstrom et al., (2009a).
Toxic chemical pollution and exposure	Short and long term health damage; morbidity and mortality.	• As per health metrics	Whitmee et el., (2015); UNEP (2013); Daughton and Ternes (1999).
Overfishing	Threat to marine food supplies. Knock-on impacts upon food webs. Destruction of marine habitat (e.g. coral reef) and associated biodiversity	• Global marine fish capture (million tonnes of fish) • Estimates of population size	Pope et al., (2010); Steffen et al., (2015); FAO (2016).
Ocean acidification	Threat to food webs, krill, shellfish, fisheries, higher sea mammals. Food supply impacts. Global losses of marine habitat (e.g. coral reef) and associated biodiversity	• Global ocean acidification (pH). • Mean hydrogen ion concentration (nmol/kg) • Global marine fish capture (million tonnes of fish)	IPCC (2013); IGBP (2013); Steffen et al., (2015).
Biodiversity loss	Threatens the regulation of many ecosystem-level processes and consequent provision of multiple essential goods and services for humanity ranging from food to medicines.	• Vertebrate biodiversity index value (1970=1) • See Box 1 for further discussion.	Worm et al., (2006); WWF (2014); Whitmee et el., (2015); Secretariat of the Convention on Biological Diversity

			(2010, 2014); Cardinale (2012)
Forest loss	While some temperate forest are growing all major tropical forests are in severe decline. Causes direct loss of forest resources	• Tropical forest loss (compared with 1700 baseline) (%)	Steffen et al., (2015).
Primary energy use	Major contributor to climate change from fossil fuel combustion. Ongoing debate concerning prior claims regarding limitations to energy production (e.g. 'peak oil'), although trends in the economic and environmental costs of future energy supply are uncertain.	• Energy use (EJ; exajoule). • Atmospheric concentrations of greenhouse gases, particularly carbon dioxide, methane and nitrous oxide. • Atmospheric concentration of CO_2 (ppm) • Mean global temperature change (^oC)	Steffen et al., (2015); Chapman (2014); Blankart, (2017).
Non-linear changes in all of the above	Past trends may disguise 'thresholds' beyond which impacts may rapidly accelerate, sometimes resulting in 'tipping point' effects where entire ecosystems are changed.	• As per the above	Barnosky et al., (2012); Regime Shifts Database (2017).
Interactions between multiple environmental threats	Where multiple threats interact to generate effects which are greater than the sum of their individual impacts.	• As per the above but across multiple metrics. • Novel chemical cocktail metrics where pollutants interact.	Whitmee et el., (2015); Barnosky et al., (2013); Regime Shifts Database (2017).

Many of the metrics listed in Table 2 are global in nature and not necessarily appropriate for decision making at a national scale. Given the challenges that face global decision making and the fact that many key decisions are made at national level. For example the National Audit Office provides a diversity of environmental and sustainability metrics for the UK (NAO, 2015). This suite of metrics not only considers national level measures of many of the items listed in Table 2, but also extends to consider physical and mental health and wellbeing indicators as well as linking to indicators of progress towards the UN Sustainable Development Goals.

While, as noted, some environmental metrics are well developed, this situation is not replicated for a number of other key measures. For example, it is well acknowledged that our understanding of the world's biodiversity is very far from complete. There are a number of competing metrics for assessing biodiversity change and this is used as an exemplar of such debate in Box 1.

Box 1: An example of competing environmental metrics: Biodiversity

- Rockstrom et al (2009a) uses "Extinction rate (number of species per million species per year)" and suggests 10 is acceptable, currently at 100 and pre-industrial is 0.1–1
  - This metric is clearly a good one to use to analyse overall global performance – but hard to see how it translates into policy – no Protected Area (PA) is going to change this figure, and generally, unless you have really high endemism (that is the entire range of a species being in one country) a country can't begin to influence this metric either – and even then would be very long term to see impact
  - One that might be more interesting is the local extinction rate, but not clear what the baseline or target would be (although obviously higher than the global extinction rate), and arguing why this figure matters necessarily relies on people, not just biodiversity
- Aichi Targets https://www.cbd.int/sp/targets/ don't really refer to specific species metrics, but instead call for a percentage of area to be within PAs (17% for land, 10% for oceans).
  - There is debate as to the benefits of PAs for biodiversity, so not the best proxy

- Also the Aichi Targets fail to specify the make-up of the habitat within that PA network. Ideally these should be representative of the country as a whole, but often this isn't the case, and instead they are just put in places with low opportunity costs

- The IUCN Red List http://www.iucnredlist.org/ is probably the most obvious metric of species vulnerability. It is very data intensive: of ~65,000 spp ~13,000 spp are threatened, while ~12,000 are data deficient
  - These categories take into account ranges, population size, and trends
  - Importantly for the following discussion, they assume (I think correctly) that it is the *percentage* change that matters, and not the *absolute* change in population size for population viability

- Mean per species viabilities, i.e. the probability that a given species can survive for a certain amount of time (usually 100 years). This is a useful metric because it allows assessments at a wide range of scales, and can require relatively little field collected data
  - Thomas et al 2004 were the first to use this approach, and rely on the Species Area Relationship which is accepted as fact (says that number of species in an area (A) = cA^z where c and $0<z<1$ are just constants). They use this 'backwards' to relate a contraction in a species' range to the probability of extinction.
  - Clements et al 2011 did a similar thing but with population size rather than range although this was criticised by Ackakaya et al 2011 because the former papers fails to use a meaningful baseline of population size (instead they choose a rather arbitrary population of 5000 individuals as sustainable).

3. Positioning Health Metrics for Environmental Sustainability: The Natural Capital approach to bringing health and the environment into decision making

One of the main reasons for developing health metrics is to assess the effectiveness of different health interventions. The same rationale drives the development of environmental metrics and in both cases this highlights one of the principal uses of metrics; as an input to decision making. Because resources, including private and public finances, are not infinite, there is always a question about the 'opportunity cost' of a given intervention; if we invest resources in a given health treatment or environmental improvement then this must at some point mean there are less resources available for alternative interventions. These trade-offs are unavoidable and arguably it is the main purpose of metrics to try and reveal these so that better decisions can be made.

While metrics quantify the effect of a given intervention, the use of metrics within decision making also reveals their greatest weakness; their lack of 'commensurability' – in other words the difficulty of comparing across metrics that are assessed in different units. This problem becomes obvious if we scan down the various rows of Table 1. The variety of different units used in health metrics makes their comparison very challenging; for example how do we compare road traffic injuries with measures of infectious disease? It was to try and improve commensurability within health metrics that generalised measures such as DALYs and QALYs were developed. However, as soon as we broaden the remit of decision making the problems of comparison across units becomes obvious.

This commensurability (or comparison) problem becomes particularly difficult if we wish to embed human health within the wider environmental sustainability debate. As can be seen through even a cursory inspection of Tables 1 and 2, there is a plethora of health and environment metrics, employing a wide variety of units. So, extending our previous example, how do we now compare road traffic injuries with measures of infectious disease with an improvement in water quality or a reduction in greenhouse gases?

The problem of commensurability is particularly challenging because the natural environment is a 'system', by which we mean that there are many linkages between different elements of the natural environment so that a change in one part typically effects other parts of the environment. For example, if we decided that, perhaps for health reasons, we should increase the production of food in an area then it is very likely that this will have other consequences. Some of these might be beneficial 'synergies'. For example, if we drain tropical swamps and use the area for food production then this might also reduce the incidence of malaria in the area. However, other effects might be detrimental 'trade-offs'. So the same swamp might have previously regulated flood waters which now endanger the livelihoods of those downstream. What is obvious here is that if we ignore these synergies and trade-offs we will get a misleading picture of the true effects of an intervention and might well end up making the wrong decisions; indeed decisions which rely on incomplete assessments could actually do more harm than good.

Given this, any attempt to promote Planetary Health through bringing human health and environmental sustainability more centrally within decision making has to address these linked problems of (i) the systems nature of the natural environment and (ii) the need to compare the trade-offs and synergies which every decision involving the environment entails. Indeed the challenge is even more demanding than described above. Real world decisions don't just involve gains and losses of health and environmental quality, they also involve trade-offs across a variety of other determinants of human wellbeing. So there are in fact many investments which would improve both health and the environment; these 'goods' are often positively related to each other. So planting a recreational woodland near to a city will not only enhance recreation and human health but also improve biodiversity and soak up greenhouse gases. But even here there is always an opportunity cost. The land used for planting might previously have been used for food production. Or the costs of planting could have provided investment for creating new jobs in industry along with the products this would have delivered. Equally importantly if we ignore these opportunity costs we also ignore the incomes and profits which drive private investments. Using a decision making system which ignores all of these important issues raises the very real possibility of limiting the applicability of assessments to a very constrained set of circumstances. This is particularly the case where only one set of metrics is considered. So, for example, if we only consider health metrics this may be useful for determining whether a health budget should be used for one intervention or another, but it cannot answer the more important question of whether the health budget itself is appropriate or not. The same applies to sole use of environmental metrics. Such approaches abandon the real, bigger decision about whether society is allocating its finite resources appropriately. Similarly any decision making system which is irrelevant to the business sector shuts itself off from influencing the larger part of global economic activity and fails before it has started.

In response to these challenges researchers from across multiple disciplines have combined with decision makers from both the public and private sector to develop an approach to decision making which can in principle address these simultaneous challenges. While terminology differs, perhaps the most common name for this way of understanding the real consequences and trade-offs of decisions is the 'Natural Capital' approach. Figure 2 provides a conceptual overview of this. Here, at the top left of the figure we see the ultimate energy and material inputs to the system (the sun and earth) generating nature's capital (those assets, such as air, water, fertile soils, etc., upon which all human wellbeing is dependent) and the natural processes (such as climate regulation, water and nutrient cycling, etc.) which maintain those assets. Moving across the figure to the right we see that the combination of natural capital and processes produces a wide array of 'ecosystem services' such as plant growth, fibre production and even medicinal resources. While some of these ecosystem services are of value in their own right (e.g. the wonder inspired by wild species), the major value to humans is derived through their combination with the services of a range of human, social, manufactured and other capital within economic production. This yields a plethora of highly valuable goods and services which are crucial to human health and wellbeing, including stable supplies of food and water, materials and defence from hazards, etc. As shown in the penultimate column, these are most natural assessed through a wide variety of good-specific natural units and metrics. While these are important measures of output and provision, their comparability is challenging and has therefore led to the development of a wide variety of methods for translating these natural units into common units conveying the wellbeing generated by changes in these goods and services. While in principle this could be assessed using any transferable, comparable unit of wellbeing, by far the most common approach is to use economic value as the common unit of account here as this readily allows decision makers to examine the costs and benefits of alternative investments of available, finite resources. Annex 2 provides a brief overview of these economic valuation methods.

The lower part of Figure 2 shows the use of this information in decision and policy making and its feedback consequences upon future use of natural and other capital. While in principle comprehensive assessments and perfect valuation should be sufficient for decision making, in practice a mix of economic cost-benefit and metric information is apprised and fed through to decisions the outcomes of which are implemented. This in turn drives ongoing use of natural and other capital and also influences future policy development and investments so that the overall system is dynamic and feeds back into itself.

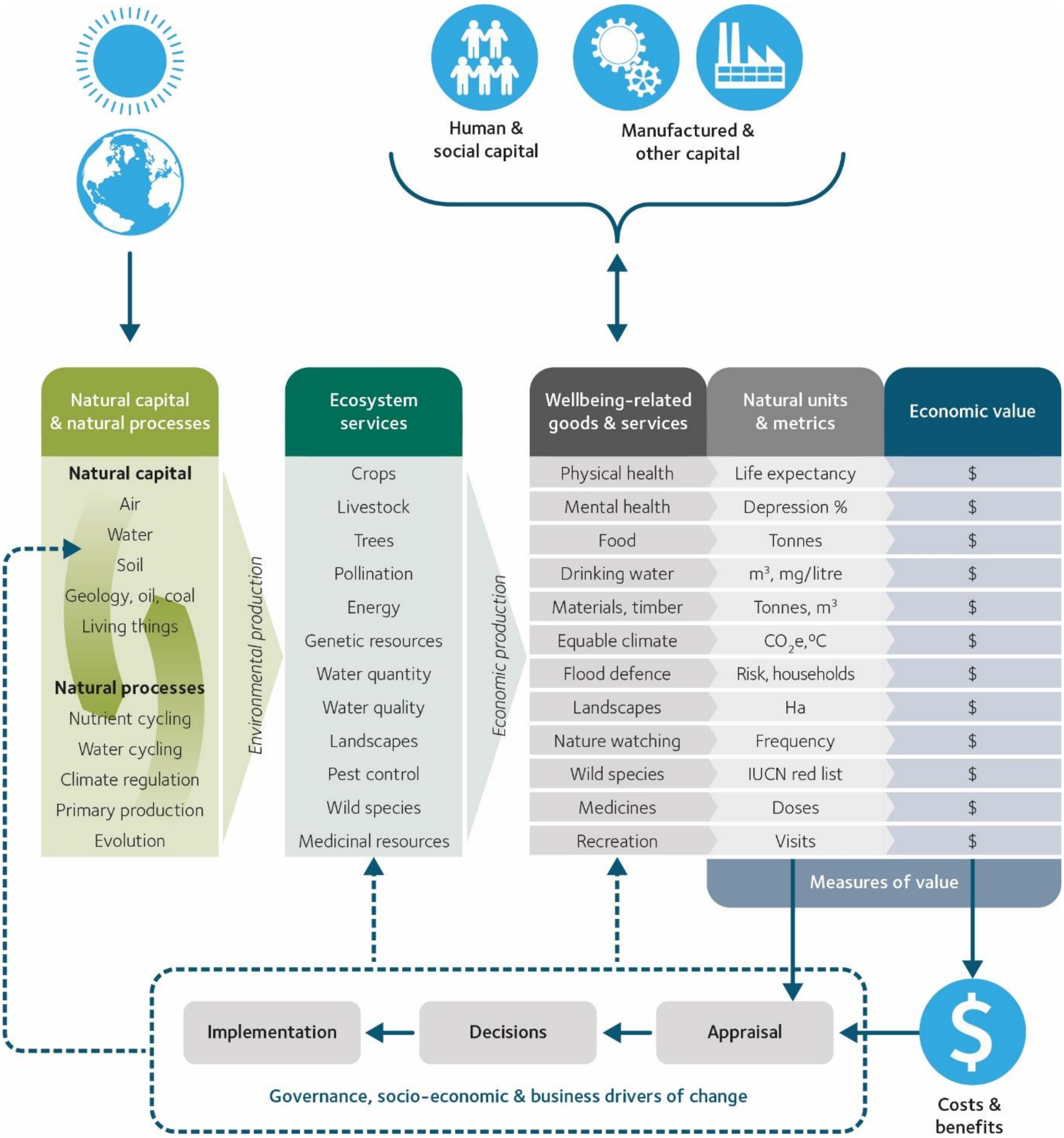

Figure 2: The natural capital approach: Bringing health and the natural environmental into economic decision making.

The natural capital approach to decision making explicitly recognises the multiple trade-offs and synergies arising from changes to the linked system that is the natural environment. Furthermore by translating those various effects into common unit economic values we have an approach to decision making which recognises the key challenges to allocating the finite resources of the earth. As with any active area of research, the practical implementation of this approach remains a focus of ongoing development and Annex 3 provides summary recommendations for a programme of research on the harmonisation of health, environmental and other determinants of wellbeing within a natural capital approach. However, the explicit recognition of the various decision making challenges which are the basis of the natural capital approach provide a powerful argument for its use as the basis of ongoing and future work of the Rockefeller Foundation Economic Council on Planetary Health. A recognition of the finite nature of resources and the inevitable trade-offs which alternative uses of those resource imply is crucial to any attempt to position human health within both the environmental sustainability debate and more general real-world decision making.

4. Choices for the Council

A fundamental choice which the Council has to make concerns the type of decisions they wish their work to influence.

If the Council wishes to solely influence the allocation of existing budgets for human health, the natural environment or the nexus between these two issues, then trade-offs with wider benefits and costs can be ignored. In this case, Section 3 of this report can be skipped and the Council can solely concern itself with the health and environmental metrics summarised in Sections 1 and 2. While many of these metrics are already in use (i.e. the Council would not be radically altering present practice), an advantage of such a restricted focus is that it avoids the complex trade-offs that arise in most of the decisions taken by government and business. However, this is also the weakness of this approach; it ignores the large majority of decisions which are not directly concerned with either health or the environment (even though they often indirectly affect both).

At the risk of over-simplification, governments are interested in improving social wellbeing while businesses are primarily concerned with enhancing long term profitability. For governments, health and the environment are just two of a long list of issues they are concerned with, including employment, education, social security, transportation, defence, etc. For most businesses, health and the environment are not key issues other than to the extent they are mandated or incentivised to consider them[10]. In essence then, if the Council choose to focus solely upon decisions which are primarily concerned with health and the environment they will make their remit much simpler but highly restricted. The large majority of government and business decisions fall outside this remit.

The Council need to decide whether they wish to restrict their focus to influencing:

(i) decisions which are already focussed upon health and/or the natural environment, or;
(ii) decisions concerning health, the environment and the wider set of issues considered by government and business.

There are arguments in favour of either option. Option (i) is simpler, less controversial and focuses solely on health and the environment (although the metrics reviewed in Sections 1 and 2 are already in use, so arguably the Council cannot fundamentally alter this). Option (ii) notes that a sole focus on conventional health and environment issues ignores the more fundamental decision about the allocation of funding and resources between these and other issues. Both options (i) and (ii) consider how to allocate available health and environment budgets, but option (ii) additionally asks whether that budget is big enough while option (i) assumes this decision has already been correctly made.

In the end this is a strategic decision for the Council which needs to determine whether its influence will be greater if the focus of its work is restricted or broadened.

[10] Other reports to the Council provide further discussion about incorporating health and the environment issues into both business regulation and incentives as well as Government legislation and agreements between countries.

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Annex 1: Health in the Sustainable Development Goals

SDG3 is "Good Health and Well-Being", but health features explicitly or indirectly in many of the other goals. These are represented in the WHO infographic below (Source: http://www.who.int/sdg/infographics/en/).

Annex 2: Methods for valuing non-market goods and services.

This Annex briefly overviews various methods for estimating the economic value of changes in health and goods and services derived from natural capital (which may themselves have health implications). The issue of health valuation is considered in greater detail in the further report to the Rockefeller Foundation Economic Council on Planetary Health by Matthew Neidell (2018).

An important issue to clarify is that prices and values are not equivalent. Indeed this is the entire basis of much welfare economics and arguably the defining difference between economics and accounting. The proof of this difference is commonplace. For example, some of the most valuable recreation sites in the world, offering unrivalled experiences to visitors, yet the price for entrance to many of these is zero. Less extreme examples abound. The price of domestic water bills is often quite modest yet the value that would be lost from the withdrawal of such supplies would be enormous. While private firms focus upon price as a key component of profit, the distinction between price and value is often the raison d'être for public policy. Economic valuation methods seek to provide public policymakers with the value estimates they require for their decision making. In this summary we overview the key methods of economic valuation but also provide some information on simpler cost-based approaches which, while not directly estimating values, may nevertheless attempt to correct some of the distortions of reliance upon a pure priced based system.

A key prior requirement of any valuation exercise is that the effects of a change are quantified. So, we can only know the value of a change if we first understand its magnitude. For this reason, economic valuation studies can often provide the spur to bring together a variety of other disciplines, including the physical and natural sciences, engineering, agronomy, etc. Such interdisciplinarity also promotes the systems thinking fundamental to a natural capital understanding of the integrated nature of the environment.

These and other basic concepts underpinning economic valuation are summarised in Box 2 which is followed by a brief overview of the key approaches to valuation.

Box 2. Basic concepts for understanding economic valuation

- **Scientific underpinning is central.** Environmental valuation relates biophysical changes to impacts on human welfare, measured in monetary terms. Thus, economic analysis is only ever as good as the natural science on which it is based.
- **Economics is anthropocentric.** Valuation reflects the benefits people derive from the natural environment. It does not attempt (and cannot be used) to assess the preferences of non-humans.
- **Values are subjective.** As human preferences change, so do the values placed on goods and services. This may be driven by social and cultural context (see for example Garber, 1989), public opinion (e.g. boycotts) or changing technologies (e.g. whale oil is no longer valued as a source of lighting and has been massively outstripped by the value of conserving living whales). Valuation incorporates these changes.
- **Prices and values are not the same** While visiting public parks may have zero price at the point of use, they clearly have value to people (Atkinson et al., 2012). Economic analyses assess these values to inform decisions. Valuation is not an attempt to commoditize nature.
- **Economic valuation is not the same as environmental accounting.** Economic valuation assesses the impact on human wellbeing of marginal changes in the provision of environmental goods and services. Environmental accounting identifies trends in natural capital depletion over time (Agarwala et al. 2014).
- **A unit of value is worth the same regardless of its origin**, meaning that health and environmental costs and benefits should be considered on par with competing demands on government budgets.

Production Function Methods

Many ecosystem services provide valuable inputs to the production of market goods, e.g. rainwater and crop pollination are crucial inputs to food production. One widely applicable strategy for valuing these services conduct an analysis of all of the various factors determining the output of a good, thereby assessing the contribution which ecosystem services play in that production (Barbier 2007, Hanley and Barbier 2009, Bateman et al. 2011). Fezzi et al. (2014) undertake such a 'production function' analysis for agricultural output in the UK and use this to estimate the value of ecosystem services such as rainfall and temperature on food output. Using this analysis they examine the consequences of future climate change on the value of UK food production.

Revealed Preference Methods

The value of many non-market, unpriced ecosystem services can be revealed by examining people's behaviour towards and purchase of related goods. For example, while many outdoor recreational amenities are free to access, visiting them often imposes travel and time costs on individuals, thereby introducing a trade-off between those costs and the wellbeing individuals experience from visits. Revealed preference (RP) methods explicitly examine this money/experience relationship to show how changes in the level of ecosystem services are reflected in behaviour and reveal individual's values (Bateman et al., 2016). For example, RP studies show how increased rates of eutrophication (an expected impact of climate change) substantially reduce the recreational value of freshwater lakes (Egan et al. 2009). Similarly, by examining the determinants of house and land prices, RP studies have revealed how people value ecosystem services as diverse as climate induced thermal comfort (Rehdanz 2006), the productivity of farmland (Schlenker et al., 2006; Schlenker and Roberts 2009), levels of road, rail and air noise (Day et al., 2007) and even the amount of snow at ski resorts (van Butsic et al., 2011). These studies also highlight that such values can vary substantially between locations, even when they are separated by relatively small distances.

Stated Preference Methods

The methods described above rely on behaviour observed directly or indirectly in existing markets. However, decision makers may be interested in assessing the value of changes that have not yet occurred. While one option is to extrapolate from existing RP data, an alternative approach is to use surveys or experiments in which subjects are presented with choices regarding proposed changes in non-market goods such as environmental quality or health (Bateman et al. 2002). For example, Chalak et al., 2012 asked consumers a series of questions concerning the amount they would be prepared to pay, in higher bills, for their utility providers to adopt low carbon technologies. Such stated preference (SP) techniques have been used widely in the valuation of health as they directly tap in to the views of the individual. Studies can examine either the willingness to pay for health improvements or the value of avoiding some defined chance of health decrements. Neidell (2018) discusses how the latter responses can be used to estimate a Value of Statistical Life (VSL), a measure commonly used for a variety of policy decisions such as the amount that transport authorities should use to reduce the number of fatalities on roads. Recent research has also sought to translate common health metrics, such as QALYs, into economic values to help health authorities allocate available funds towards effective treatments (Baker et al., 2010; Donaldson et al., 2011; Robinson et al., 2013; Pennington et al., 2015). Particular attention has also been given to the estimation of values for key groups such as the elderly or children (Alberini et al., 2010). When the goods in question are familiar and respondents believe their responses are likely to feed directly into actual payments, then stated preference (SP) techniques can be a useful valuation tool where there is a lack of observable behavioural data. However, if these conditions do not hold then a number of number of biases can afflict SP responses (Day et al. 2012).

Value transfer methods

The methods outlined above can require considerable investments of time and resources to implement robustly. But when decision makers need low cost information at short notice, value transfer (VT) methods can amalgamate information from previous studies to obtain defensible values relevant for the decision in question (Plummer 2009, Richardson et al. 2015). More sophisticated variants of VT analyse the determinants of previous values, accounting for variation in the nature and quality of environmental changes being assessed, the spatial distribution of resources and their substitutes, the proximity to populations and so on. This information is then combined into a VT function (Bateman et al. 2011), the parameters of which can be applied to the characteristics of the situation being considered by decision makers to yield a suitably adjusted estimate of value. Recent extensions have combined such functions with the spatial analytic capabilities of a geographical information system (GIS) to permit the estimation of value surface maps. For instance, Brander et al (Brander et al. 2012) apply such techniques to value the expected impact of climate change on European wetlands from 2000-2050.

Cost-based (non-valuation) methods

Despite the wide range of valuation methods outlined above, some ecosystem related goods and services remain difficult to value, e.g. the value of avoiding future floods and storm surges arising from sea level rise. Here avoiding damages and degradation entails much lower costs than repairing them subsequently (Heal et al. 2005, Day and Couldrick 2013) and replacement costs (the costs of replacing natural with man-made defences) are often higher than the costs of conserving natural defences (Heal et al. 2005). Damage cost assessments have been undertaken for a variety of environments, ranging from inland floods to coastal erosion with costs assessed in terms of the reduction in expected damages (Barbier 2007, Barbier et al. 2013).

A further variant of cost-based methods is to impose an impact constraint and then estimate the cost of meeting it. This approach was used to incorporate biodiversity goals into the UK-National Ecosystem Assessment because of concerns regarding the robustness of SP assessments of the non-use value of biodiversity (UK-NEA 2011, Bateman et al. 2013). This has clear parallels with the marginal abatement cost approach to valuing carbon emissions (Morris et al., 2012) and as in that case it is important to remember that the cost of meeting a given conservation target is very unlikely to equal the value of the biodiversity conserved.

Annex 3: Research recommendations for harmonising health, environmental and other determinants of wellbeing within a natural capital approach.

- Continue to measure important environmental health hazards and potential for interventions to reduce them (e.g. based on existing frameworks such as SDGs, WHO Environmental Burden of Disease)
- Also consider metrics capturing the more complex interdependences and opportunities for good environments to promote and support health and wellbeing, these might include:
    - % of working population commuting through active travel modes
    - % of population meeting the WHO greenspace availability measure (WHO 2016)
    - Measures of pharmaceuticals and derivatives in aquatic ecosystems
    - Areas of tranquillity in urban areas
    - Equity of access to (or residence within) good environmental conditions
    - Value of physical activity in outdoor environments (White et al. 2016)
    - DALYs/QALYs gained through positive environmental intervention
- Build more sophisticated metrics that capture the array of multiple positive and negative environment-health circumstances for populations
- Build methodologies to analyse and communicate these complex data, especially trading off of risks and benefits
- Ensure metrics capture inequalities and variation in vulnerability – especially where exposure to risk, or potential benefit, is inequitable
- Create platforms/database with linked human health and environmental data to look at acute and long term effects of co-benefits, interventions etc. on humans and the natural environment over time – and to project into the future.
- Understand the environmental, policy, economic, social and behavioural drivers of change in the natural environment and our use of its resources.
- Improve scientific knowledge of the consequences of environmental change, recognising the interactions inherent in a natural capital view of the environment.
- Improve the efficacy and ease of use of methods for the economic valuation of changes in health and the environment
- Develop natural capital decision support tools to help decision makers in business and the public sector understand the consequences of different actions and investments.