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Chapter 3

The Current State of our Data and Knowledge

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Executive summary

There is a growing demand for environmental indicators and analysis, particularly analysis that addresses interlinkages across different environmental domains and between the environment, society and the economy (*well established*). There have been advancements in terms of collecting official statistics related to the environment, including geospatial statistics, particularly in terms of promoting environmental economic accounting and building geospatial information systems, which contribute to environmental monitoring. However, there are still methodological gaps in measuring some aspects of the environment, there is very limited information which links people and the environment, and there are capacity gaps in countries attempting to build their environmental information systems. {3.2}

Measuring the nexus between gender and the environment has been identified as a high priority, as women and men, in many contexts, have differing rights over and access to the environment (*well established*). Women and men have different vulnerabilities to environmental degradation and hazards, and often play different roles in environmental management decision-making. Currently, only limited time series data and statistics are available on the gender-environment nexus. {3.5}

Much environmental data collection is part of one-off studies or projects, limiting their usefulness (*well established*). Through the Sustainable Development Goals (SDGs) there has been a global recognition that monitoring the environmental dimension of development will require regular, standardized data collection, which can translate into time series statistics and indicators, including time series for geospatial data products. This will increase the emphasis on compiling high-quality information based on international best practices. {3.7}

Transforming the provisioning of environmental data and statistics will require new and innovative means of data collection, (*well established*) including new partnerships with the private sector, multilateral institutions, space agencies, non-governmental organizations and other partners. {3.8}

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3.1 Introduction

This section provides an introduction to environmental statistics and data and covers the state of existing data and knowledge that contribute to any environmental assessment, including national-, regional- and global-level assessments. It attempts to elaborate the state of data collection and the use of data to compile statistics and produce indicators. Emerging areas of statistics, such as big data, citizen science and traditional knowledge – which are currently underutilized, but present tremendous opportunities for better measuring – are discussed in Chapter 25 of this report.

3.2 The demand for environmental statistics and data

Knowledge and data are essential bedrocks of environmental assessment. Without an evidence base to work from, conducting and publishing an accurate assessment is impossible. But what is an evidence base, and how do we generate it?

'The Environment' was traditionally considered to refer only to biophysical earth systems. But this paradigm is shifting. It is important not only to measure the state of the environment, but also to determine how environmental problems, which manifest in the biophysical environment, arise from social systems and economic arrangements, and how economic development and social well-being depend on the environment.

The GEO-5 report chapter on the *Review of Data Needs* presents the deficiencies in scientifically credible data on the environment; in particular, the report notes the need for time series on freshwater quantity and quality, groundwater depletion, ecosystem services, loss of natural habitat, land degradation, chemicals and waste, and other issues (United Nations Environment Programme [UNEP] 2012). It also acknowledges that the factual and scientific quality of an assessment rely on the quality and availability of data on the environment (UNEP 2012). Further, it indicates that more systematic data-collection can help governments, as well as regional and international bodies, to assess their progress towards international goals.

In his 2015 Millennium Development Goals (MDG) Report, Ban Ki Moon **(Box 3.1)** (United Nations 2015a) called for urgent and rapid improvements in data for the post-2015 agenda, especially its availability, reliability and timeliness. He urged governments to make substantial investments in their national statistics offices and systems, as well as to scale up the capacity and capability for producing high-quality data.

The Drivers, Pressures, State, Impact, Response (DPSIR) conceptual framework (see Section 1.6) is a useful framework for environmental monitoring and assessment. Many of the drivers and pressures of environmental change are located in the social realm, and so are many of the impacts. Many environmental challenges are the result of inequalities in access to resources and institutions of power, as well as along the axes of gender, age, race, ethnicity, income and other social status.

As highlighted in the GEO-5 report (UNEP 2012), there is a need not only for regular monitoring data, but also for harmonization of data-collection approaches and methodologies. Governments rely on national statistical systems to provide the necessary data for national policy; however, historically, many national statistical systems have not considered environmental statistics to be within their purview.

Box 3.1: Statement from Ban Ki Moon, 2015

"Strong political commitment and significantly increased resources will be needed to meet the data demand for the new development agenda."

Ban Ki Moon, 2015 (United Nations 2015)

3.3 History of environmental statistics

Historically, official statistics have risen in response to a clear demand from governments for information. The first Roman census was justified by the need for accountability in terms of taxation and military service (Hin 2007). National accounts were born out of the stock market crash of 1929 and the need for wartime statistics, which would allow countries to avoid economic catastrophe and provide information on how to pay for World War II (Stone 1947; Vanoli 2005). In 1947, the United Nations established the United Nations Statistical Commission (UNSC) to develop and promote statistical guidelines which could be used by countries for national monitoring. The scope of the Commission's work covers statistical methodologies for keeping stock of the economy, and for policy on global macroeconomic stability, including economic growth, price movements and population dynamics, migration, mortality, births and longevity – but not the environment.

The Brundtland Commission of 1983 led to the Framework for the Development of Environment Statistics which was first adopted by the UN Statistical Commission in 1984. Later, the UNSC worked on environmental economic accounting which arose from the 1992 Earth Summit. There have been three revisions of the System of Environmental Economic Accounts (SEEA) these include the SEEA 1993, the SEEA 2003 and the SEEA 2012 – the latest was adopted as a statistical standard in 2012 (United Nations 1993; United Nations *et al*. 2003; United Nations 2012). Additionally, the Experimental Ecosystem Accounts were adopted in 2013. The link between these two statistical frameworks forms the basis for monitoring progress towards sustainable development and focuses on the effects of life on the environment and that of the environment on life.

There was a 91 per cent participation by countries and territories in the 2010 census round, and a 95 per cent submission rate of national accounts to the United Nations Statistics Division (United Nations 2015b; United Nations 2017a). However, for the first six decades of the UNSC, progress in official statistics was mostly related to demography and economic statistics. The adoption of the MDGs, which included goals focused mostly on social development, and the desire to track progress as measured by the MDG indicators was transformational in terms of increasing investment in statistics. The MDG implementation efforts resulted in increased statistical capacity of countries to produce and use statistics on poverty, education, health, gender, environment and governance (World Bank 2002; Organisation for Economic Co-operation and Development [OECD] 2015; United Nations 2016a).

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Environmental statistics and statistics disaggregated by location, gender, age, poverty and other factors were not a focus of MDG monitoring and therefore received less investment. These areas are a focus of the SDGs; however, many challenges remain in terms of measuring different aspects of the environment and also in creating disaggregated statistics.

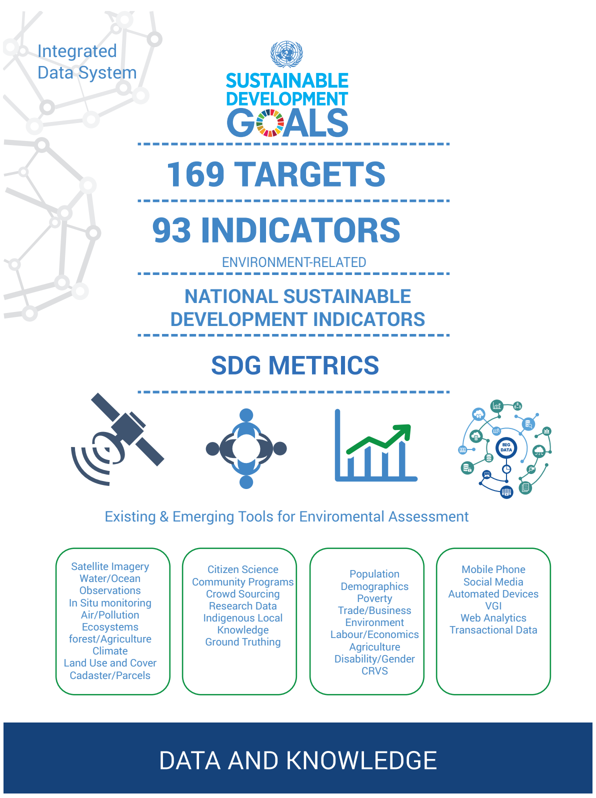
3.4 Better data for a healthy planet with healthy people

Improved environmental data and statistics are required for many levels of decision-making, for environmental assessments at the local, national, regional and international levels, and for analysis of the interaction between the environment and the economy and society. A robust environmental statistics system, which is geospatially disaggregated, would ideally provide information that could be used for different purposes and at different levels.

3.4.1 Measuring the environmental dimension of sustainable development

The context within which this report is produced is one where the MDGs have run their course. In September 2015, the United Nations General Assembly endorsed *Transforming Our World: The 2030 Agenda for Sustainable Development*, a global development agenda which captures goals and targets needed to achieve economic, social, and environmental development (A/RES/70/1). The Sustainable Development Goals (SDGs) represent a move away from treating social development in isolation towards an approach aimed at sustainable prosperity, dignity for people, and a healthy planet through national action and partnerships.

Figure 3.1: SDGs data and knowledge framework



In the quest for achieving these ambitious goals, the SDGs are defined around 17 goals, 169 targets and 244 indicators (inclusive of duplication) (United Nations 2017b). *Transforming Our World…* clearly notes that data requirements for the global indicators present a tremendous challenge to all countries. One study estimated that an investment of US$ 1 billion per annum will be needed in order for lower-income countries to monitor the SDGs (Sustainable Development Solutions Network 2017). Thus, as highlighted in the 2016 SDG report, tracking progress on the SDGs will require a shift in how data are collected, processed, analysed and disseminated, including using data from new and innovative data sources (United Nations 2016b).

Although the SDG framework creates monitoring challenges, it also creates opportunities. It represents the first time that there has been an attempt to holistically include environment-related indicators in a global monitoring framework. Although the SDG framework has set out indicators for measuring across all 17 SDG goals, many of the indicators lack a statistical methodology. This is recognized in the framework by assigning each indicator to one of three tiers **(see Figure 3.2)**. The inclusion of a broad range of environment-related SDG indicators can be used to leverage increased investment in environmental statistics and to promote their use.

Figure 3.2: SDG indicator status

Tier 1 Indicator	Indicator has an internationally established methodology and data are regularly produced by 50 per cent of countries.
Tier 2 Indicator	Indicator is conceptually clear, but data are not regularly produced by countries.
Tier 3 Indicator	No internationally established methodology or data collection.

Source: United Nations (2018, p.3)

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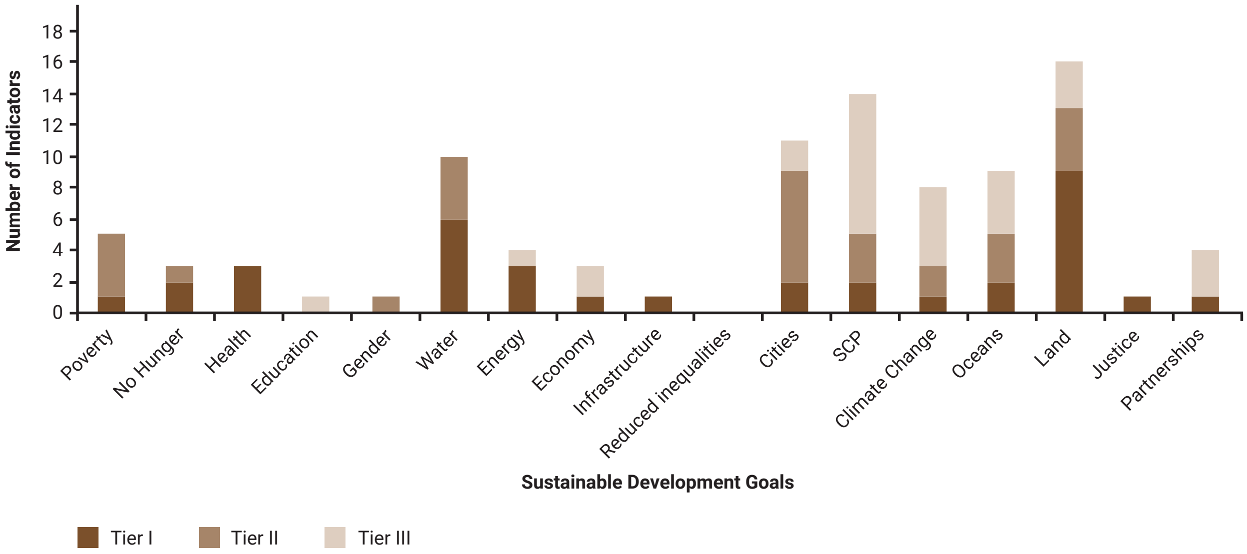
Figure 3.3: Environment-related SDG indicators by goal and tier



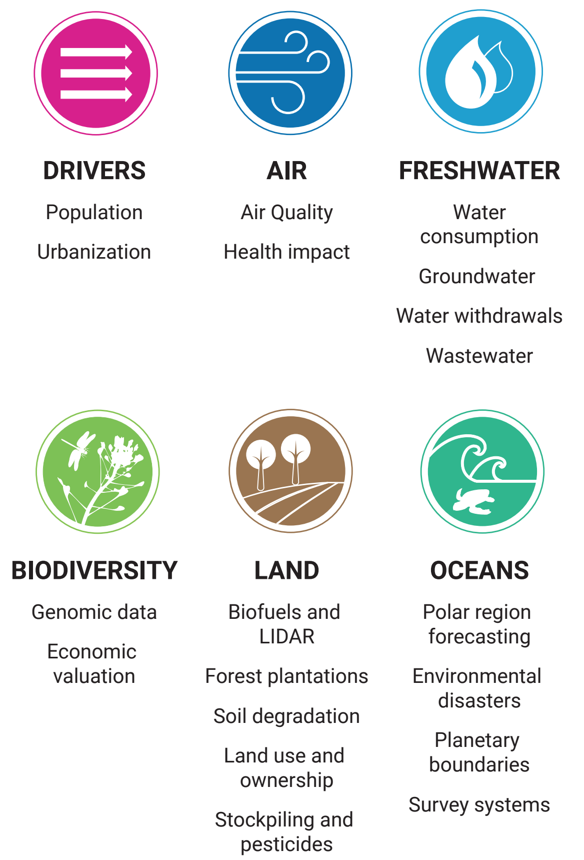
Source: United Nations (2018).

There are 93 SDG indicators directly related to the environment **(Figure 3.3)**. There are also a number of additional indicators that are indirectly related to the environment (e.g. poverty, zoonotic disease, nutrition and life expectancy, economic growth, inclusive societies and policy processes which are not included in **Figure 3.3**). The environment-related SDG indicators are spread across all of the SDGs, with at least one environmentally relevant SDG indicator for each, except Goal 10 – which reflects the cross-cutting nature of the SDGs and the interactions between people, the environment and the economy. However, of the 93 environment-related SDG indicators, only 34 currently have an existing agreed methodology and data that are available from most countries (Tier I). The other indicators have either been given a Tier II or III status (27 and 34 indicators, respectively) by the Inter-Agency and Expert Group on the SDG indicators **(Figure 3.4)**.

Monitoring the environmental dimension of the SDGs will not only require research and development in terms of statistical methodologies but will also require investing in environmental statistics and utilizing new data sources to achieve a data revolution. Traditional data collection by national statistical offices cannot be the only source of data, but countries will need integrated data systems which bring together official statistics, earth observation, citizen science, big data and traditional knowledge. Integrated data systems can bring many sources of information together to provide a more complete picture. Environmental data integration includes:

- bringing together ethnographic information about environmental changes as experienced on the ground;
- a participatory understanding of personal experience; indigenous and traditional knowledge; geospatial information about people and the environment;
- combined information on the environment and women, the poor, and other vulnerable groups in order to reveal patterns and challenges hidden in other systems of knowledge;
- knowledge from Big Data on sustainable consumption and production patterns; and
- poverty dynamics within and between contries, some dimensions of which can be revealed by satellite observations of 'the earth at night' or deforestation boundaries.

Figure 3.4: GEO-6 major data gaps organized by respective chapter



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A new approach to data and knowledge systems with increased emphasis on an evidence-based approach to decision-making is crucial to meet the various SDGs. By placing these systems at the forefront for all end users, cross collaboration can be innately encouraged to foster new skills, technologies, and sources of data. In turn, our knowledge of sustainable development will improve, alongside our understanding of the SDGs. However, organizational and methodological challenges will arise regarding data privacy, ownership and use (Sustainable Development Solutions Network 2017).

3.4.2 Thematic data gaps

In almost all thematic areas (including biodiversity, land, air, water and oceans), available data are lacking **(Figure 3.4)**, particularly in developing countries. Environmental indicators linked to industrial activities are easier to measure and monitor, for example energy consumption or water use. Land cover and ecosystem extent can be assessed on a broad scale using satellite remote sensing, but not always with the necessary resolution. The effects of environmental change, air and water pollution, and other environmental conditions are particularly difficult to measure (UNEP 2012); hence the need to explore a paradigm shift on environmental monitoring approaches – depicting the social orientation and complementing the approach with physical attributions.

The following is a brief description of some of the major data gaps from the thematic chapters in Part A of this report.

Drivers (Chapter 2)
National-level population data are relatively sound for most countries due to government census requirements, but weaknesses arise from aggregation across sectors of the population. National census data are generally insufficient to answer important intra-household questions, such as contraception use and access, fertility, household decision making and family structure (e.g. age of marriage). To be properly understood, these and other variables should be disaggregated by age, gender, race and other socioeconomic factors. Urbanization data are plagued by similar issues of national aggregation. There is a lack of information on small and medium-sized cities, and inconsistency in the scale of reporting. For both population and urbanization, there need to be standard agreements on statistics at a global scale, and greater consistency and coverage. Other significant data gaps include rural to urban migration, the role of nuclear households, the distribution of benefits provided by technology, and patterns of production and consumption. Uncertainty also exists in the myriad factors affecting economic development, and dependencies between this and other drivers. For example, financial estimates of the cost of unsustainable practices and impacts of climate change require greater accuracy and transparency, given that, while numbers exist, there is low confidence in their accuracy.

In addition to gaps in raw data, gaps exist in the mechanistic understanding of the driver processes. Future technologies and events will alter the global landscape and qualitatively change the roles of other drivers. For example, automation may change the nature of transportation, which would have flow-on effects to many other areas. The impact of climate change on human health requires better analyses and understanding of current and future links between these factors. More data are needed on the effect of climate change on human demographics, including migration estimates at finer scales (McMichael, Barnett and McMichael 2012). There is sectoral imbalance in knowledge on the effects of climate change, with impacts on the energy sector being well understood, while impacts on land use, ecosystem processes and functions, and intersectoral issues are not.

Air (Chapter 5)
An overarching issue with air quality data is that, unlike meteorological variables, few air pollutant concentrations are measured with sufficient spatial and temporal coverage. Therefore, the effects of most chemicals are estimated by using other (measured) chemicals as proxies, which is likely to be inaccurate in many cases. For example, only a few persistent, bioaccumulative and toxic substances are measured, and their data are globally patchy. Where monitoring does exist, it is biased towards developed countries, compromising analyses of air pollution versus human health in developing countries. There is a general need for capacity-building to facilitate the measurement of air pollution in developing countries, both for national benefit and to complete global coverage. Bias in air quality sampling also exists within countries, and there is a need for more sampling in areas of low socioeconomic status (e.g. informal or slum dwellings).

Impacts of air quality on human health gained attention in the Global Burden of Disease Study – a global study of factors influencing human health (World Health Organization [WHO] 2018), which elevated air pollution to a top priority. Instead of relying only on cities that have air quality monitoring, satellite data and modelling were used to estimate air pollution at large scales (Brauer *et al.* 2016). Additionally, there are currently few consistent global emissions inventories. Inventories are gathered or modelled in some regions, but data quality and sources vary. There are, however, consistent inventories available at a European level and at international level for a selection of pollutants (e.g. under the United Nations Economic Commission for Europe Convention on Long-range Transboundary Air Pollution).

Efforts should focus on greater sampling coverage and/or modelling, potentially with sensors or satellites. The Copernicus programme aims to measure a number of air quality variables on a regular basis and provide data for all countries. Another European initiative for data reporting is the Air Quality Directive, which provides for statistical data that are produced annually, and an online map of air quality that is updated every 6 hours.

Biodiversity (Chapter 6)
Biological data and knowledge are sparse compared with the complexity and diversity of biological systems. In general, data paucity increases at finer spatial scales, and at higher taxonomic resolutions. Estimates of the total number of species vary between 2 million and 13 million (Costello, Wilson and Houlding 2012; Scheffers *et al*. 2012), with the majority (86 per cent of terrestrial species, and 91 per cent of oceanic species) believed to be undescribed (Mora *et al.* 2011). Invertebrates and deep-sea ecosystems are particularly poorly described. Biologists increasingly use genetic information to identify species (a technique known as DNA barcoding) (Hosein *et al.* 2017), but more traditional taxonomy is still needed to describe morphological traits.

Gaps in data of ecological processes and ecosystem and community structure are even greater than gaps in species information. Examples include ecosystem function and services, which are understood conceptually but are often difficult to measure. A consequence of this is an inability to effectively prevent species invasions, which is considered by some to be the second greatest threat to global biodiversity (Doherty *et al*. 2016).

There is substantial uncertainty in the extent of climate change impacts on biodiversity, and bioinformatic challenges in processing the volume of earth observation data relevant to climate-driven biological change (e.g. in forest cover). Current solutions to such big data problems include change-detection software, which minimizes the need to store data for every fly-over, and multidimensional data structures such as 'data cubes', which manipulate large amounts of raster data efficiently.

Global initiatives to advance biological data include the Convention on Biological Diversity's Global Taxonomy Initiative (Siebenhüner 2006) and the Global Biodiversity Information Facility (GBIF) (Yesson *et al.* 2007). GBIF species occurrence records now cover all parts of the globe (1 billion records referring to 1.7 million species); (GBIF 2018), and its taxonomy follows the Catalogue of Life (http://www.catalogueoflife.org) using established Biodiversity Information Standards (TDWG) for data transfer (http://www.tdwg.org/).

Much indigenous ecological knowledge (e.g. medicinal plants) is translated by word of mouth and risks being lost if undocumented (McCarter *et al.* 2014). However, a framework has recently been developed for connecting indigenous knowledge with other knowledge systems (Tengö *et al*. 2013), such as international assessments (Sutherland *et al.* 2014), and some indigenous knowledge is now captured digitally (Liebenberg *et al.* 1999; Stevens *et al.* 2014).

In addition to data gaps, there are deficiencies in data sharing and access. Some biological problems are inherently regional or global and require coordinated multinational management. A field where this is a major problem is transnational environmental crime (White ed. 2017), which includes harvesting, transporting and tracing trade of endangered species, illegal mining, fishing and deforestation. Improvements in shared data infrastructure are essential for effective regulation in this area.

Oceans (Chapter 7)

Ocean data have many gaps, which is unsurprising since satellite observations cannot penetrate below surface waters. Most oceanic data are collected by direct measurement or modelling, so it is difficult to obtain good coverage for a vast environment that extends over 70 per cent of the earth's surface. Some issues exist through lack of global coordination, as both coral reefs and marine litter lack global databases. The National Oceanic and Atmospheric Administration (NOAA) maintains the largest coral reef database, but it does not draw upon all sources globally. Similarly, marine litter data are collected by different countries with different protocols and have not been globally consolidated. In addition to litter abundance and distribution, significant knowledge gaps exist regarding the ecological impacts of marine litter, including the toxicity of ingestion, impacts of nanoparticles, microplastics, and how plastics ingested by fish impact human consumption.

Global fish catch data are maintained by the Food and Agriculture Organization of the United Nations (FAO), to which all countries report national catch and yield. Commercial fishing catches are well monitored in developed countries, but are almost certainly underestimated since illegal fishing constitutes as much as 40 per cent of all catch in some areas (Agnew *et al.* 2009). In countries with fewer resources to devote to reporting, fishing estimates are often based on a small number of samples and are therefore less reliable. Research vessel costs are a major impediment to obtaining fisheries-independent data, particularly in developing countries where even catch monitoring in ports may not be economically viable.

Land (Chapter 8)

Land is one of the most data-rich domains due to the effectiveness of earth observation in monitoring land surfaces, but there are still notable data gaps and quality issues. Earth observation generally measures the quantity rather than the quality of change, and is unable to measure certain processes. For example, there is agreement that land degradation has increased, but it is not done often and is inconsistently measured. The interrelationships between the Normalized Difference Vegetation Index (NDVI) and land degradation are often difficult to generalize and transfer, since land use and biophysical conditions are changing regionally. While forest cover data have improved since the mid-1990s and some broad-scale data are maintained by FAO, other data exist in multiple databases that are not always comparable. Soil erosion, salinization, desertification and change in ecosystem services are all difficult to measure from satellite images, and there are questions as to the appropriate scale of observation. There is no global database or standardized measurements of soil erosion, preventing a globally coherent or comprehensive assessment. Other difficult areas are land tenure and cadastral (map-based) information, since there is no global standard for defining land use, and systems are not comparable across countries.

Freshwater (Chapter 9)

Data on fresh water suffer from spatial and temporal patchiness, and a divide between variables than can be remotely sensed by earth observation versus those that cannot (Lawford *et al.* 2013). Data-deficient areas at all scales include water quality, water consumption, groundwater quantity, water withdrawals and wastewater. The SDGs require monitoring of ambient water quality, but not all countries have the capacity or will to meet these reporting requirements. There are better data for surface-water quality than for groundwater, but these are still patchy. Earth observation systems measure optical qualities of water (chlorophyll, salinity, turbidity), but cannot measure nitrogen or phosphorous concentrations. In recent years, progress has been made in using satellite data from the GRACE mission to estimate changes in groundwater storage (depletion), but assessing groundwater resources requires the collection of direct data which are relatively expensive as they require access to groundwater through wells or boreholes. There are also gaps in glacier, snow and ice data, and uncertainty around impacts of climate change (Salzmann *et al.* 2014), though the Copernicus programme may address this on a global scale with a satellite dedicated to monitoring snow/ice cover. Some other variables are difficult to measure by any means, such as groundwater and saltwater intrusion, which are mostly understood by modelling rather than observation. These models are in urgent need of reliable on-the-ground data for calibration and verification. Geopolitical issues of water use, such as transboundary water sharing, are another area requiring more data, particularly at times of water scarcity.

Citizen science may offer some solutions to issues of freshwater sampling coverage and basic monitoring of groundwater levels. Examples include the use of mobile applications to monitor water quality (Lemmens *et al.* 2017) and the use of testing kits in EarthWatch Freshwater Watch (http://www.freshwaterwatch.thewaterhub.org/) and other volunteer groups (Overdevest *et al*. 2004). An early form of citizen science has successfully been deployed for many decades in Netherlands where volunteers from across the country measure groundwater levels in piezometers bimonthly, contributing to the building up of long-term time series of groundwater data in the country. However, citizen science initiatives usually involve simple water monitoring and do not measure the suite of modern pollutants such as antibiotics, persistent organic pollutants, current use pesticides, microplastics, nanoparticles and endocrine disruptors.

3.5 Gender and social-environment intersectionality

The paradigm shift that is bringing social analysis into the heart of environmental assessment has developed since the mid-1990s with the emergence of gender-disaggregated environmental analysis and analysis focused on other vulnerable groups. This section will focus on the gender-environment nexus; however, many of the issues presented could be applied to other vulnerable groups. Broader equity issues, including, importantly, North-South inequalities in environmental footprints and impacts – which are themselves gendered – are addressed elsewhere in this report.

The role of gender in environmental analysis will accelerate as the social equity and equality commitments of Agenda 2030 shape global policymaking **(Box 3.2)**.

At the heart of gender analysis is the understanding that virtually all environmental relationships, including drivers and impacts, are 'gendered'. Socially constructed gender roles and norms position men and women differently in relation to the environment. Men and women are often exposed to different environmental problems and risks; in turn, this may mean that men and women have different perspectives on the extent and seriousness of environmental problems, and on what solutions might best be attempted or deployed. Further, because of the social construction of gender roles, men and women are often positioned differently in terms of being able to take action or being taken seriously as agents of environmental interpretation and change.

Gender analysis requires new approaches to the structure of environmental inquiry. Analysing the environment through a gender lens requires new and different questions, brings to the foreground different dimensions of human-environment relationships, and requires different methodological tools and approaches. Gender analytical lenses encompass 'the environment' in both its physical and social aspects, and in the interactions of these. Gendered commitments to "lift the roof off the household" in data collection reveal intra-household dynamics of resource utilization and decision-making, which are often critically important in understanding local environmental behaviour and environmental outcomes (Seager 2014).

Gender analysis also brings to the fore intersectionality – an understanding that social relationships with the environment are seldom shaped by a single social identity, but rather by a combination of gender identities and norms, as well as other social identities such as race, sexuality and class.

The UNEP *Guidelines for Conducting Integrated Environmental Assessment* (UNEP 2017) reflect these new approaches by bringing to the fore gender-informed questions that should be integrated into environmental assessment from the earliest planning stages **(Box 3.3)**.

Data availability and statistical systems have not kept pace with the interest in and demand for gender-disaggregated analysis in environmental assessment. The GEO-5 assessment notes the lack of – and need for – gender-disaggregated environmental data (UNEP 2012). One of the most consistent messages in the field of gender-disaggregated environment analysis is that this information is crucial to a comprehensive analysis (United Nations 2015a; UNEP 2016). Some progress has been made since the GEO-5 assessment, and UNEP (2016) synthesizes the data and analytical approaches that are now

Box 3.2: Gender statistics

"Gender statistics are defined as statistics that adequately reflect differences and inequalities in the situation of women and men in all areas of life…First, gender statistics have to reflect gender issues, that is, questions, problems and concerns related to all aspects of women's and men's lives, including their specific needs, opportunities and contributions to society. In every society, there are differences between what is expected, allowed and valued in a woman and what is expected, allowed and valued in a man. These differences have a specific impact on women's and men's lives throughout all life stages and determine, for example, differences in health, education, work, family life or general well-being. Producing gender statistics entails disaggregating data by sex and other characteristics to reveal those differences or inequalities and collecting data on specific issues that affect one sex more than the other or relate to gender relations between women and men. Second, gender statistics should adequately reflect differences and inequalities in the situation of women and men. In other words, concepts and definitions used in data collection must be developed in such a way as to ensure that the diversity of various groups of women and men and their specific activities and challenges are captured. In addition, data collection methods that induce gender bias in data collection, such as underreporting of women's economic activity, underreporting of violence against women and undercounting of girls, their births and their deaths should be avoided…"

Source: UNSD (2015)

available. Nonetheless, very little information is available about the different needs of men and women, their different use of resources, and their different responsibilities in contributing to conservation and sustainable development.

Even less information is available to support intersectional analysis of gender with age, race, caste or class dynamics. Existing data on gender and the environment are fragmented and scattered among small and often grey-literature sources or across hard-to-access scholarly reports. There are almost no common standards or complementarities across countries, making it almost impossible to aggregate and compare issues across regions. The lack of sufficient long-term data further impedes gender-disaggregated environmental assessment because relationships between gender and the environment may only become evident over long time periods.

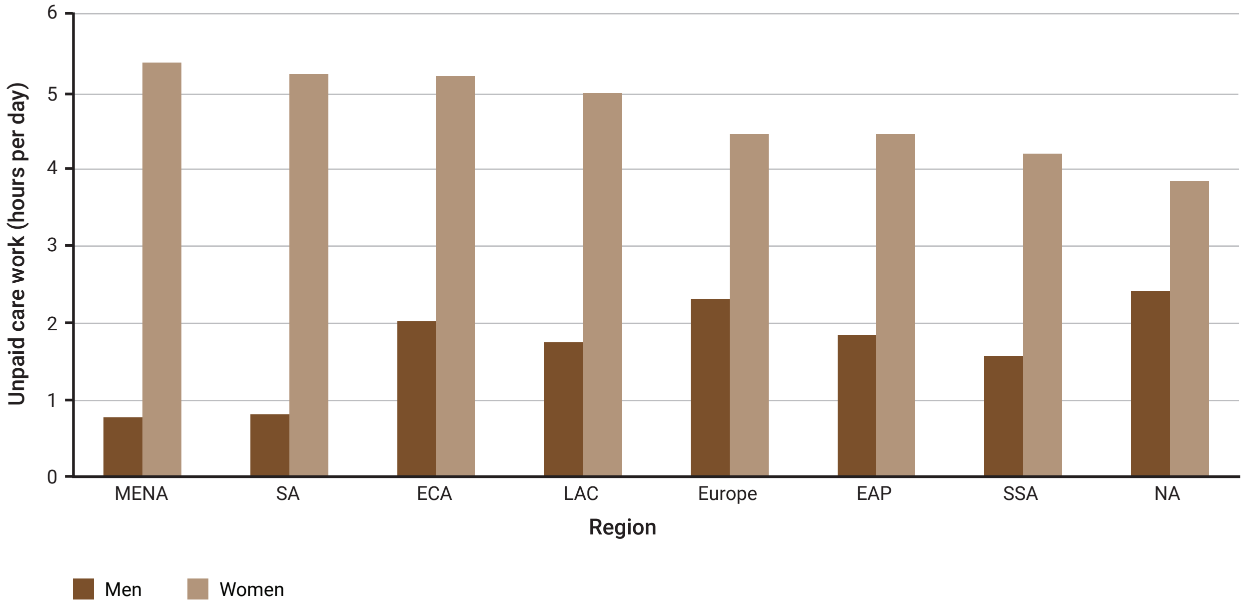
Box 3.3: Gender-informed questions

- ❖ What are the geographic locations and subject areas, sectors and activities in which gender difference and social class impact one's relationship with the environment?
- ❖ Are there any other intersectional issues that might need to be considered (e.g. how different cultural/ethnic/class groups use, imagine and/or relate to place and are there any conflicts between these groups)?
- ❖ How do general differences between socioeconomic classes, in relation to the environment (as mapped in reports such as the *Global Gender and Environment Outlook*, UNEP 2016) apply to the environmental issues undergoing assessment?
- ❖ What are the differences in behaviour of men, women, boys and girls in relation to the environmental issues undergoing assessment (as mapped in reports such as the *Global Gender and Environment Outlook*?
- ❖ Are gender-disaggregated data available to understand that relationship or will it need to be collected?

The absence of gender data undercuts the momentum towards further gender-environmental analysis – 'what's not counted is assumed to not count'. In the absence of data, environmental assessments remain partial; establishing baselines, monitoring progress and assessing outcomes are almost impossible. Progress towards SDG commitments to gender equity and equality in all domains, including the environment, will be impossible to measure without substantial improvement in gendered data.

Even simple gender-disaggregated data-based analysis, such as that on average time spent in unpaid work by men and women **(Figure 3.5)**, can reveal important gender dynamics. The burden of unpaid work restricts women, more than men, from undertaking paid work and from participating fully in civil and economic spheres. Figure 3.5 illustrates the uneven burden of unpaid work between men and women. Many hours of women's unpaid work, especially in poorer countries, are spent in directly managing local environmental resources to meet the needs of household water, fuel and food. At the same time, 'time poverty', which is produced by the burden of unpaid work, means that women are less likely than men to be available for environmentally relevant training, nor are they available to participate in formal processes relating to environmental use, management and decision-making.

Figure 3.5: Unpaid care work



MENA, Middle East and North Africa; SA, South Asia; ECA, Eastern and Central Africa; LAC, Latin America and the Caribbean; EAP, East Asia and the Pacific; SSA, sub-Saharan Africa; NA, North Africa.

Source: Ferrant, Pesando and Nowacka (2014, p. 2).

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The expectation that environmental assessments will include gender analysis and data is achieving mainstream acceptance. In 2016, UNEP produced the *Global Gender and Environmental Outlook* (GGEO) entirely through a gender lens. The GGEO report concluded that the effectiveness of environmental decision-making would be enhanced by "Strengthening the focus on developing, collecting and analysing gender-disaggregated data, indicators and other information, including at the intra-household level." (UNEP 2016, p. 201).

The SDG target 17.18 specifically calls for improved collection and availability of gender-disaggregated data: "By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts" (A/RES/70/1).

The GGEO provides a summary of the most complete gender-disaggregated data sets available as of 2016. These include several gender-disaggregated agricultural indices (from FAO) on indicators such as agricultural employment and landholders; cross-national comparative information on access to and ownership of land (from FAO, the Organization for Economic Co-operation and Development [OECD] and the World Bank); and sex-disaggregated burden-of-disease data for a few environmental factors (Prüss-Ustün *et. al*. 2017).

Additional large-scale efforts are under way to collect and analyse environment-related gender-disaggregated data:

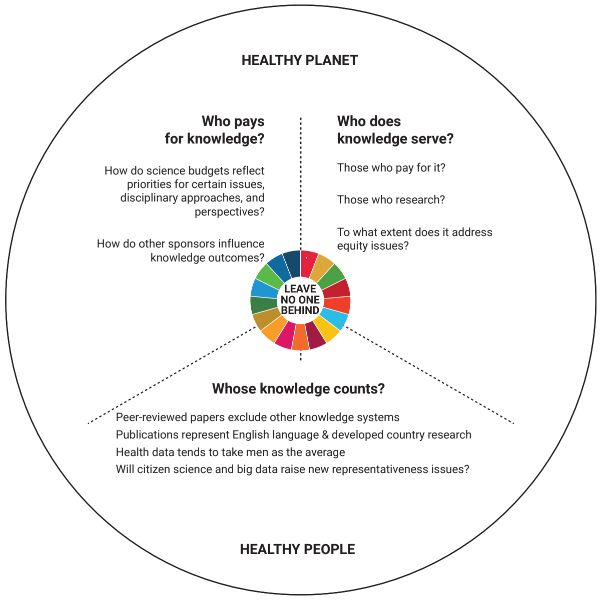
- in 2014, the United Nations Educational, Scientific and Cultural Organization (UNESCO) launched a project to identify gender and water priority indicators (UNESCO 2014);
- the FAO Gender and Land Rights Database "was launched in 2010 to highlight the major political, legal and cultural factors that influence the realisation of women's land rights" (FAO 2018). By 2018, the FAO database had data from more than 80 countries, and the FAO 'Legal Assessment Tool' maps the intricacies of men's and women's access to land.

The prospects for improving gender-disaggregated environmental data are promising and the expectations for data collection for the SDGs should accelerate efforts to systematically collect both sex-disaggregated (indicators specifically related to biologically rooted activities, roles and impacts), as well as gender-disaggregated (related to social roles and impacts) environmental data. There remains, however, a considerable gap between demand and supply.

3.6 Equity and human-environment interactions

Assessing human-environment interactions requires data, knowledge and integrated approaches as outlined in Chapter 1 of this report. A balanced evaluation of existing data and scientific results can lead to balanced policy choices. However, is the knowledge base able to provide a balanced story about human-environment interactions? This leads to three key questions, as shown in **Figure 3.6**.

Figure 3.6: Equity questions in data and knowledge



Who pays for data and knowledge and for what sorts of data and knowledge? All data and research are funded by specific actors – the state, but also non-state actors such as civil society, industry and philanthropists. There is clear evidence that states invest large sums of money in natural science and technology research, but there is significantly less invested in environment- and resource-related social science and equity-related research. For example, a study of funding in the United States of America shows that between 1970 and 2015 social sciences received very little funding in comparison with other fields of study (National Science Foundation 2017).

Whose interests do the existing data and knowledge serve? Research questions and data tend to serve dominant interests, for example those identified by the funding agencies. They may also serve disciplinary interests rather than human-environment interactions more integratively (McMichael, Butler and Folke 2003). Furthermore, although there is need for data and knowledge on the causes and impacts of internally displaced people, such data are not yet available (Bennett *et al*. 2017, p. 11). The need for disaggregated data is vital to address issues of equity, but such data and knowledge are limited.

Whose data and knowledge counts and why? In international assessments there is increasing evidence that researchers come from the richer 'developed' world, rather than the non-English speaking and/or developing world. For example, 87 per cent of the world's researchers, 92 per cent of the research budget and 94 per cent of scientific publications come from the G20 countries (UNESCO 2015). In 2015, the majority of authors in the Intergovernmental Panel on Climate Change (IPCC) came from developed countries with significantly fewer from developing countries (Schulte-Uebbing *et al.* 2015).

There is little assessment in any of the environmental literature of the politics of data and knowledge, and this is challenging.

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3.6.1 Environment and economy

A number of SDGs depend for their realization on understanding and properly taking into account the costs and benefits of environment-economy relationships. Most importantly, the SDGs and natural capital accounting indicators provide insight into the value of 'nature's contributions to people', human societies more broadly, and of the cost of residuals such as pollution and waste. The economics of nature or natural capital accounting involve the assessment, measurement, aggregation and valuation of these contributions, to help policymakers ensure that this value is reflected in the economic activities of production, consumption, trade and investment through such instruments as pricing, costing and regulation. Evaluating the economic dimension of the environmental impacts of economic activities helps policymakers realize synergies between economic and environmental issues, gain efficiency in the allocation of limited resources and avoid trade-offs (or minimize them where they are inevitable). Any such evaluation should take into account that economic activities are increasingly characterized by global chains (e.g. investment, trade), and the role of such 'teleconnections' is crucial in determining overall impacts. Therefore, what we do to sustain environmental resources in one place may be at the expense of resources or environmental quality elsewhere. The System of Environmental Economic Accounts provides a framework for analysing the interactions between the environment and the economy. It includes information on four policy quadrants, namely: access to services and resources; managing environmental resources supply and demand; the state of the environment; and risks and extreme events (United Nations 2014).

When considering the benefits of nature, a fundamental issue is whether these values are comparable with and substitutable by other economic benefits. Most conventional economic analysis assumes substitutability of factors of production, called 'weak sustainability', when applied to natural capital (Solow 1974; Hartwick 1977). But there are many instances when the contributions of nature to human life (e.g. the regulation of the climate) cannot be provided by other human activities. These situations of 'strong sustainability', often related to the planetary boundaries, need to be revealed through robust analysis. Such analysis will need to rely on methodological diversity, using insights from ecology, economics, social and cultural studies, and recognizing their dynamic evolution.

In natural capital accounting and in the System of Environmental Economic Accounting, methodologies may be used to give monetary value to environmental benefits and costs, so that they may be compared with other economic activities and costs. Alternatively, in some cases, only the stocks and flows of environmental resources and residuals are measured using an accounting framework as opposed to including a valuation. An accounting framework provides information on the use of environmental resources, such as water and energy, and the residual to the environment, such as emissions and wastes, by industrial classification.

For economic valuation, the valuation should always be applied in a way that it can capture trade-offs and the demand for resources for competing uses. It should also be recognized that there are numerous environmental situations in which, due either to lack of data or absence of credible science or methodological agreement, economic analysis has limited scope.

Economic analysis of the environment can be oriented towards the wider goals of the United Nations system, and the SDGs related to peace, human rights, equity and security, as well as sustainability. It needs to recognize the complexity of environmental-economic interactions and highlight uncertainties, through clear and simple communication.

Sustainability, and the policies necessary to achieve it, should focus on trends in per capita wealth, as well as flows of income and non-monetary benefits. It is the natural capital stock that generates nature's contribution to people, and correct wealth accounting in relation to the environment and resources, avoids the mixing up of income and wealth.

Macro-models are required to assess national and global outcomes of policies for the use of resources and the environment. Recent results from use of these models suggest that the conventional perception of the economy and environment having a trade-off relationship may be incorrect. Increasingly, 'green economy' analyses seem to suggest that natural resources are an essential input to sustainable economic growth. From this perspective, an appropriate 'economics of nature' could be a great enabler of both conservation and development. Such messages need to be transmitted with clarity and confidence.

3.6.2 Environment and health

The environments in which we live are a key determinant of human health and well-being. The physical environment provides us with the air we breathe, the food and water required for sustenance, solar radiation that provides heat and light, and more. These are direct effects, but indirect effects are also important in supporting healthy ecosystems, which in turn provide food security and other ecosystem services. The social environment also has a strong influence on health and well-being, as clearly shown through socioeconomic gradients in health, whereby social disadvantage is associated with poor health and well-being across a wide range of diseases and health-risk behaviours (Friel and Marmot 2011). Degradation of our environment (e.g. air pollution, contamination of food and/or water, insufficient or excessive sun exposure, excessive noise, conflict and war) adversely affects food and water security, health and well-being.

Exploring the links between the environment, in its broadest sense, and human health and well-being requires measurement of the 'exposure' (the environmental factor of interest) and the 'outcome' (some measure of health and/or well-being). The next step is to assess whether there is a causal relationship between the exposure (e.g. air pollutants, conflict, green space, noise) and the outcome, which typically requires good study design, appropriate statistical methods, and causal analysis. The size of the effect, coupled with an understanding of the prevalence of the exposure in the population, can be used to provide an attributable effect (i.e. what proportion of the health outcome is caused by exposure to the environmental risk factor) (Prüss-Ustün *et al.* 2017). In addition to analysing exposure to certain contaminants, analysis of environmental conditions and health and well-being can also reveal underlying relationships between health and the environment. For example, data on underweight children, malnutrition and other food security indicators can be analysed through an environmental lens to better understand the relationship between climate change and food security, health and well-being.

Environmental exposure can be directly measured at the individual level (usually only for relatively small numbers of people) or inferred at the individual level or at an ecological level using data from routine monitoring (e.g. of air and water quality, levels of solar radiation, or modelled, for example using combinations of atmospheric variables to estimate climate change-related exposures). These methods can also be combined, for example, where data from multiple weather stations are used to calculate individual exposures at different locations within an area (Miranda *et al.* 2016). Exposure measurement is more precise for some environmental factors (e.g. blood lead levels) than for others (e.g. lifetime exposure to noise pollution) (Klompmaker *et al.* 2018), and for short-term rather than long-term (e.g. lifetime) exposures. Here, large sample sizes ('big data'), plus innovative study designs and data analysis, are required, but there must also be recognition of the potential biases within these 'noisy' data sets (Ehrenstein *et al.* 2017).

Data to assess the burden of the health outcome with environmental factors are available at the individual level through epidemiological studies, and from administrative databases (e.g. hospital separations data, where modern data linkage methods can allow examination of individual-level data). However, considerable challenges remain to using administrative data due to ethical issues around protection of individual privacy. Administrative data can also be used in ecological studies (e.g. of the effect of air pollution on hospital admissions). For some health outcomes in some countries, surveillance through disease registries provides comprehensive and accurate incidence and mortality data. These can be linked to other data sets to derive associations at an individual level (Korda *et al.* 2017), or used in ecological studies to assess relationships between disease and environmental parameters (Adams *et al.* 2016). The Global Burden of Disease (GBD) Study is a valuable data set for disease-specific incidence and mortality (GBD 2016 Causes of Death Collaborators 2017; GBD 2016 Disease and Injury Incidence and Prevalence Collaborators 2017). The GBD is now updated annually and seeks to collect the best possible health (typically disease) data from all countries to provide comprehensive estimates at the global, country and, for some countries, regional levels. In addition, the GBD Study estimates health loss through morbidity, as well as disability adjusted life years (DALYs) and health adjusted life expectancy (HALEs) (GBD 2016 DALYs and HALE Collaborators 2017). However, additional disaggregated information on who is impacted and on location, which would be necessary for a comprehensive assessment, is typically not available. Recent developments in 'omics' technologies – genomics, metabolomics, exposomics, epigenomics and others – deliver a huge amount of data that may allow assessment of the effects of environmental exposures on human health and well-being. However, challenges remain in separating out effects of specific exposure (e.g. the various components of 'air pollution') and accurately quantifying effects attributable to exposures:

a) that are difficult to measure precisely,
b) have non-linear dose-response or threshold effects,
c) when exposure levels change over life, or
d) have both risks and benefits to human health.

3.7 Existing data systems

Official statistics, national geospatial data, and Earth observation monitoring data often are not part of a single data system at the national level, and there is a need for better integration of data from these sources in assessments. Although gaps remain in official statistics, national geospatial data and Earth observation data, these data sources are currently being used for environmental assessment and are better developed globally than the emerging tools for environmental assessment presented in Chapter 1.

3.7.1 Official statistics

The disciplines of official statistics and Earth observation have developed independently and manifestations of their interconnectedness have been sporadic. The relationship has benefited from guidance emanating from the national statistical systems through the following developments: adoption of the System of Environmental Economic Accounting (SEEA) under the Central Framework in 2012, adoption of the SEEA Experimental Ecosystem Accounts in 2013 and the revised Framework for the Development of Environment Statistics in 2013. These three statistical frameworks provide an increased methodological basis for statistics; however, there is still a need to scale up statistical production and to involve more actors in the production of environment statistics, including local-level actors. Additionally, there remains a need for methodological guidance on the interactions between society and the environment, including the gender dimension.

Technological change – including better satellite data, monitoring stations and personal electronic devices – is changing the data landscape, including through citizen science. The data revolution and its technological derivatives, namely big data and citizen science, unleashed new possibilities for measurement, potentially disrupting existing organizational and institutional relationships in the management of measurement and production of scientific knowledge. The response to these new manifestations of technology-inspired measurement have been led by, among others, the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). However, it is likely to be long before the urgent need of integration is achieved. There remains a need to better utilize technologies, including mobile applications, smart devices and other tools, to make data accessible to populations and to provide an interface for making citizen science data discoverable.

The imperative for statistics and data
The injunction of 'leaving no one behind' imposes a high premium on the production and delivery of disaggregated data by all attributes possible, including (importantly) by local area. In so doing, the SDGs bring to bear the importance of

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geospatial data and statistics. A geospatial statistical approach to measurement provides a transformative infrastructure that improves the information necessary to 'leave no one behind' through analysis of interactions and causality at the local level and for particular populations.

The SDG indicator framework
While the SDG agenda is bold and ambitious, it is not possible to cover everything at the same time. Therefore, the ability to prioritize and sequence is strategic for success in the delivery of measurement to the global agenda. So, which data, which statistics and which indicators?

An attempt to answer the questions cannot be made without historical experiences of global development measurement exercises, of which the MDGs represented the most enlightening. In his 2015 MDG report, the United Nations Secretary-General notes with regret that, first, statistical information is collected with a major temporal lag. Yet, today's world is a fast moving one requiring real-time data; second, that the information is highly aggregated and lacks locational specificity for use in directing interventions; and third, there is minimal resource allocation to countries and institutions that require data the most for development (for their people and environment).

That the nature of the problem has been defined does not imply that the questions the problem raises should not be answered. The benefit of defining the problem is in identifying with a greater level of clarity what needs to be done in prioritizing and sequencing.

With regard to indicators, official statisticians, under the guidance of the UNSC, have worked hard to identify an indicator framework and the feasibility of indicators that would feed into the framework. However, the design of the framework has, in practice, been directed towards the number of indicators, rather than to an architecture that would determine the indicators. The existence of the framework and the ability to identify indicators feeding into the framework is a commendable start.

In relation to the Global Environment Outlook, it is more important to note that the task becomes even more serious and politically challenging given that tens of the goals in the SDGs relate directly to or are closely linked to the environment. Perhaps this will lead to a different GEO outcome.

As defined in Section 3.1, less than a quarter of the environment-related SDG indicators are Tier I. This gives some idea of the difficulty of measurement, including resourcing of the statistics systems, in some countries.

The former United Nations Secretary General has recognized the need for clear coordination mechanisms for data and statistics. In this regard, the Secretary-General called on countries to recognize the significance of coordination among national agencies **(Box 3.4)**, including national statistical institutions, in providing, encouraging and enforcing compliance with statistical standards through principles, legislation and practice notes.

Box 3.4: Statement from the United Nations Secretary-General

"National statistical offices should have a clear mandate to lead the coordination among national agencies involved and to become the data hub for monitoring."

Ban Ki Moon, United Nations Secretary-General 2007-2016, (United Nations 2015a)

Measuring the environment in the context of the SDGs
Accurately assessing the interaction between people and the environment will require new data sources and new tools for environmental assessment. For example, geospatial information can be incorporated with population maps to determine the regional environmental issues that affect people (e.g. where poor people live and where water quality issues are).

The key driver to the exponential growth of access to and use of technology has been the ability of technology to create and push towards common standards. Through this innovation, a movement has emerged towards standardized forms of data to be collected at a much lower cost. This has made collection of larger amounts of data a lot more attractive. More importantly, technology has unleashed possibilities for the use of geospatial statistics and a greater ability to observe changes in the environment.

Environmental data, statistics and knowledge are the foundations of successful environmental assessments. Remote technologies, Earth observation systems and national statistical offices remain the leading generators of environmental data. New and emerging knowledge frameworks and data capacities in database management, citizen science, disaggregated social and gender analysis, big data, data visualization tools, spatial modelling, social media and the Internet offer opportunities to collect and disseminate information. Collectively, data aggregated from these approaches improve capacity to support strategic decision-making processes that are based on wide-ranging and multidisciplinary knowledge. Effective monitoring of environmental trends is critical to clean up environmental damage.

The disaggregated and location-based information needed to 'leave no one behind' is believed to be achievable, and this meets the requirements for effective monitoring of environmental trends.

If we are, however, true to the notion of 'leaving no one behind' as prescribed in the SDGs, then multiple methods need to be handled by information management systems. These include the well-established traditions of statistical standards and the future of statistics is enhanced with the availability and analysis potential of land information systems. Furthermore, new technologies and their capabilities in the data and geographic space create new ways for citizens to participate in science and also to increase the possibilities of environmental data integration.

The challenge, however, for these new knowledge platforms to be useful, is if they are supported by an institution. First, can they be seen as systems of today and tomorrow that attract reasonable resources, and that enhance the well-being of people and the planet? The 2015 MDG report of the United Nations Secretary-General argues the need for coordination and involvement of national agencies in monitoring (see Box 3.5). Second, can these data and information systems work together across space and time? That is, can they be trusted to help social, economic and political discussions, and also withstand times of transition? Third, are they auditable? Will they stand up to scrutiny? Fourth, knowledge, statistics and data are inherently political and can create challenges to governments in the knowledge discourse.

Underlying challenges

Major data gaps, across the globe and across environmental domains, limit our ability to identify trends and manage unwanted outcomes. In many countries, official statistics on the environment are rarely generated, are difficult to access, are scattered across different institutions, and reporting is fragmented (UNEP 2016). Across many environmental topics, data availability is geographically unbalanced, being scarcer for rural areas and developing countries. Monitoring systems from global to regional scales are fragmented, lack coverage and are often not updated on a regular basis (UNEP 2012, p. 129). There is a pressing need to create regular monitoring that follows commonly agreed international standards that are best enacted through international cooperation. There is also a need for increased sharing of data in a standardized format, for example, data that is compliant with Statistical Data and Metadata e-change standards.

3

The United Nations SDG report of 2016 explains that data requirements for the global indicators are almost as unprecedented as the SDGs themselves, and constitute a challenge for many countries. Tracking progress on the SDGs would require the collection, processing, analysis and dissemination of an unprecedented amount of data and statistics at the subnational, national, regional and global levels, including those derived from official statistical systems, as well as from new and innovative data sources (United Nations 2016b).

While knowledge systems often cross national boundaries, the creation, custodianship, distribution and use of knowledge have historically and politically been associated with governments. Knowledge does not exist in a geopolitical, social or economic vacuum. Will these new systems be able to inform political decision making and acceptance of environmental development and management?

3.7.2 Geospatial information

Environmental monitoring and forecasting systems have been growing rapidly. However, combining information from multiple systems to generate statistics and indicators remains a major challenge. Earth observation is defined by the global Group on Earth Observations as both surface observations (*in situ*) and those collected by aircraft and remote sensing, including from satellites and other space missions. Similarly, a data set collected for one purpose can often be used for multiple purposes. For example, agricultural land cover could be useful for understanding natural disaster risk, examining the migration of people, the nature of informal settlements, urban infrastructure and their relationship with biodiversity and ecosystems.

Earth observations and environmental monitoring are being transformed through integration of administrative data from national statistical agencies, including economic data, and open data policies for Earth observations that benefit both emerging economies and developed countries. Open Earth observations, citizen science, social media, and digital platform or big data access can stimulate a transformation to a new model for creating data which results in more inclusive, social, robust knowledge for decision-making, where there is broader understanding and access to policy-relevant knowledge.

For example, the first *Atlas of the Human Planet* (Pesaresi *et al.* 2017), derived from the Global Human Settlement Layer (GHSL), provides a validated source of information on human habitations, from villages to megacities. The baseline data, spatial metrics and indicators related to population and settlements, developed in the frame of the Group on Earth Observations Human Planet initiative, provide users with a baseline data platform for monitoring and analysis. The GHSL resource is an example of the potential of public data to support global, national and local analyses of human settlements and, in particular, support policy and decision-making. This application of Earth observations is essential for evidence-based modelling of human and physical exposure to environmental contamination and degradation, as monitored through multilateral environmental agreements; disasters as encompassed by the Sendai Framework for Disaster Risk Reduction; the impact of human activities on ecosystems, as measured by the Convention on Biological Diversity; and human access to resources, assessed by the SDGs (European Commission 2018).

In September 2015, the United Nations General Assembly endorsed *Transforming Our World: The 2030 Agenda for Sustainable Development*, a global development agenda to use to monitor progress on economic, social and environmental aspects of sustainability, as stipulated in Article 76 **(Box 3.5)** (A/RES/70/1).

Within the United Nations system, agencies including the UNSC InterAgency Expert Working Group (IAEG-SDG) and the United Nations custodial agencies taking a lead in developing monitoring methodologies are examining, and in some cases preparing to incorporate, Earth observation and geospatial data for support of the SDGs, its targets and indicators. A 2016 analysis by the Group on Earth Observations estimated that at least 98 targets and indicators could benefit from and use

Box 3.5: Article 76 of the 2030 Agenda

"We will promote transparent and accountable scaling-up of appropriate public-private cooperation to exploit the contribution to be made by a wide range of data, including Earth observation and geo-spatial information, while ensuring national ownership in supporting and tracking progress."

– United Nations, General Assembly (2015)

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Earth observations data (United Nations 2016c). The Earth observations global community is fully engaged and ready to provide expertise to all United Nations members, particularly developing countries, with regional and specific national capacity-building.

3.8 Conclusion

Gender and social-environment intersectionality
The differences in exposure to environmental problems and risks result in different perspectives for men and women, thereby reflecting unequal reaction to and interpretation of opportunities for development and sustainability. Since the environment is shaped by a blend of social identities and norms, improved collection and strengthened analysis of high-quality and timely disaggregated data by gender, age, race and other characteristics in the national contexts are required to establish a holistic baseline, and for monitoring and assessment. Such data should also be spatially disaggregated and geographically sensitive to capture local variations.

Equity and the human-environment interactions
Collection, disaggregation and analysis of data for the most vulnerable communities remain a challenge. More work in this area would better capture issues of inequality (United Nations 2012, p. 12). Industry generally funds research that helps improve industrial processes and increase shareholder value, while philanthropists may cover a range of issues including equity issues. It is important to promote data and knowledge on how "to overcome barriers to political and social participation and to accessing services and proactive policies and sustained social communication to influence social norms that perpetuate discrimination and exclusion" (United Nations 2012, p. 9). Furthermore, in terms of regional concentration, research is concentrated geographically in the United States of America, China, Japan and Germany, which collectively account for 63 per cent of the global research and development expenditures, mostly funded by the business sector (National Science Board 2016, pp. 41-46). Businesses as funders of research have overtaken government-led funding, which has moved the balance towards more applied research than basic research (United States National Science Board 2016). This issue raises the question of who is reaping the benefits of research and if a greater good is achieved by it.

Environment and economy
Economic evaluation of environmental impacts involves the overall assessment of nature's contributions to the lives of people; the accounting of global economic activities, investment and trade to people and the environment; and the comprehensive institutional issues affecting equity and market operations. Specific findings on sustainability can only be revealed through a robust analysis, covering ecological, social and cultural factors, and their interaction over time. Valuation attributes a monetary values to environmental benefits and costs, as well as trade-offs and competition. Economic analysis of the environment should be oriented towards the wider scope of the SDGs, including peace, equity and security. The monetary and non-monetary values in relation to the environment and resources, as well as models reflecting the economics of nature, can only be generated through timely and reliable data and information from statistical surveys and other new data sources such as big data.

Environment and health
Combined physical and social environments have strong influences, both direct and indirect, on human health and well-being. With this, the measurement of linkages between the 'exposure' and 'outcome', the assessment of causal relationships, and the exposure to populations need strong statistical bases and large sample sizes (i.e. big data). Challenges facing epidemiological studies include data protection, reliability and disparity when using administrative databases. Recent developments include the use of big data to allow assessment of long-term environmental exposures. It is necessary to explore the use of other sources of information to validate the long-term effects of human activities and natural disturbance such as climate change on health, with the use of new forms of data and knowledge (i.e. citizen science and traditional knowledge).

3.8.1 Better data for a better planet and better lives

The United Nations 2030 Agenda serves as the global framework for assessing economic, social and environmental development, focusing on building a healthier planet and fostering better lives through national engagement and partnerships. Monitoring the progress on the SDGs requires shifts in data collection, analysis and dissemination, including using environmental statistics, geospatial data, Earth observation and new data sources (i.e. citizen science, big data, traditional knowledge).

A new and innovative approach to data and knowledge systems with an aligned focus on evidence-based information gathering is essential for achieving the ambitious SDG framework. However, monitoring the entire SDG framework over the 2016-2030 period is estimated to cost as much as a quarter of a trillion dollars (Jerven 2014). So, in addition to improving data systems, there is also a need for priority setting to target data collection and improve efficiencies.

Environmental change is difficult to measure, and the effects of environmental change are even more complicated to measure, especially in relation to identifying causes. A shift from focusing solely on the physical dimensions to including social orientation, economic value and impacts on health and well-being is crucial but is a challenge for even well-developed statistical systems.

References

Adams, S., Lin, J., Brown, D., Shriver, C.D. and Zhu, K. (2016). Ultraviolet radiation exposure and the incidence of oral, pharyngeal and cervical cancer and melanoma: An analysis of the SEER data. *Anticancer research* 36(1), 233-238. https://www.ncbi.nlm.nih.gov/pubmed/26722048.

Agnew, D.J., Pearce, J., Pramod, G., Peatman, T., Watson, R., Beddington, J.R. *et al.* (2009). Estimating the worldwide extent of illegal fishing. *PLoS ONE* 4(2), e4570. https://doi.org/10.1371/journal.pone.0004570.

Bennett, K., Bilak, A., Bullock, N., Cakaj, L., Clarey, M., Desai, B. *et al.* (2017). *Global Report on Internal Displacement.* International Displacement Monitoring Centre and Norwegian Refugee Council. http://www.internal-displacement.org/global-report/grid2017/pdfs/2017-GRID.pdf.

Brauer, M., Freedman, G., Frostad, J., van Donkelaar, A., Martin, R.V., Dentener, F. *et al.* (2016). Ambient air pollution exposure estimation for the global burden of disease 2013. *Environmental Science & Technology* 50(1), 79–88. https://doi.org/10.1021/acs.est.5b03709.

Costello, M.J., Wilson, S. and Houlding, B. (2012). Predicting total global species richness using rates of species description and estimates of taxonomic effort. *Systematic Biology* 61(5). https://doi.org/10.1093/sysbio/syr080.

Doherty, T.S., Glen, A.S., Nimmo, D.G., Ritchie, E.G. and Dickman, C.R. (2016). Invasive predators and global biodiversity loss. *Proceedings of the National Academy of Sciences* 113(40), 11261-11265. https://doi.org/10.1073/pnas.1602480113.

Ehrenstein, V., Nielsen, H., Pedersen, A.B., Johnsen, S.P. and Pedersen, L. (2017). Clinical epidemiology in the era of big data: New opportunities, familiar challenges. *Clinical epidemiology* 9, 245-250. https://doi.org/10.2147/CLEP.S129779.

European Commission (2018). *GHSL - Global Human Settlement Layer*. http://ghsl.jrc.ec.europa.eu/.

Ferrant, G., Pesando, L.M. and Nowacka, K. (2014). *Unpaid Care Work: The Missing Link in the Analysis of Gender Gaps in Labour Outcomes.* Centro de Desarrollo de la OCDE. Paris: Organisation for Economic Co-operation and Development. https://www.oecd.org/dev/development-gender/Unpaid_care_work.pdf.

Food and Agriculture Organization of the United Nations (2018). *What is the GLRD?* http://www.fao.org/gender-landrights-database/background/en/.

Friel, S. and Marmot, M.G. (2011). Action on the social determinants of health and health inequities goes global. *Annual review of public health* 32, 225-236. https://doi.org/10.1146/annurev-publhealth-031210-101220.

GBD 2016 Causes of Death Collaborators (2017). Global, regional, and national age-sex specific mortality for 264 causes of death, 1980-2016: A systematic analysis for the Global Burden of Disease Study 2016. *Lancet Global Health Metrics* 390(10100), 1151-1210. https://doi.org/10.1016/S0140-6736(17)32152-9.

GBD 2016 DALYs and HALE Collaborators (2017). Global, regional, and national disability-adjusted life-years (DALYs) for 333 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990-2016: A systematic analysis for the Global Burden of Disease Study 2016. *Lancet Global Health Metrics* 390(10100), 1260-1344. https://doi.org/10.1016/S0140-6736(17)32130-X.

Global Biodiversity Information Facility (2018). *Free and open access to biodiversity data*. https://www.gbif.org/.

Hartwick, J.M. (1977). Intergenerational equity and the investment of rents from exhaustible resources. *American Economic Review* 67(5), 972-974. https://www.jstor.org/stable/1828079.

Hin, S. (2007). *Counting Romans.* Princeton/Stanford Working Papers in Classic Stanford University. https://www.princeton.edu/~pswpc/pdfs/hin/110703.pdf.

Hin, S. (2007). *Counting Romans.* Princeton/Stanford Working Papers in Classic Stanford University. https://www.princeton.edu/~pswpc/pdfs/hin/110703.pdf.

Hosein, F.N., Austin, N., Maharaj, S., Johnson, W., Rostant, L., Ramdass, A.C. *et al.* (2017). Utility of DNA barcoding to identify rare endemic vascular plant species in Trinidad. *Ecology and Evolution* 7(18), 7311–7333. https://doi.org/10.1002/ece3.3220.

Jerven, M. (2014). *Data for Development Assessment Paper: Benefits and Costs of the Data for Development Targets for the Post-2015 Development Agenda.* Copenhagen Consensus Center. https://www.copenhagenconsensus.com/sites/default/files/data_assessment_-_jerven.pdf.

Klompmaker, J.O., Hoek, G., Bloemsma, L.D., Gehring, U., Strak, M., Wijga, A.H. *et al.* (2018). Green space definition affects associations of green space with overweight and physical activity. *Environmental research* 160, 531-540. https://doi.org/10.1016/j.envres.2017.10.027.

Korda, R.J., Clements, M.S., Armstrong, B., K., Di Law, H., Guiver, T., Anderson, P.R. *et al.* (2017). Risk of cancer associated with residential exposure to asbestos insulation: A whole-population cohort study. *The Lancet Public Health* 2(11), e522-e528. https://doi.org/10.1016/S2468-2667(17)30192-5.

Lawford, R., Strauch, A., Toll, D., Fekete, B. and Cripe, D. (2013). Earth observations for global water security. *Current Opinion in Environmental Sustainability* 5(6), 633–643. https://doi.org/10.1016/j.cosust.2013.11.009.

Lemmens, R., Lungo, J., Georgiadou, Y. and Verplanke, J. (2017). Monitoring rural water points in Tanzania with mobile phones: The evolution of the SEMA App. *ISPRS International Journal of Geo-Information* 6(10), 316. https://doi.org/10.3390/ijgi6100316.

Liebenberg, L., Steventon, L., Benadie, K. and Minye, J. (1999). Rhino tracking with the CyberTracker field computer. *Pachyderm* 27, 59-61. https://www.iucn.org/backup_iucn/cmsdata.iucn.org/downloads/pachy27.pdf#page=60.

McCarter, J., Gavin, M.C., Baereleo, S. and Love, M. (2014). The challenges of maintaining indigenous ecological knowledge. *Ecology and Society* 19(3), 39. http://dx.doi.org/10.5751/ES-06741-190339.

McMichael, A.J., Butler, C.D. and Folke, C. (2003). New visions for addressing sustainability. *Science* 302(5652), 1919-1920. https://doi.org/10.1126/science.1090001.

McMichael, C., Barnett, J. and McMichael, A.J. (2012). An ill wind? climate change, migration, and health. *Environmental health perspectives* 120(5), 646–654. https://doi.org/10.1289/ehp.1104375.

Miranda, A.I., Ferreira, J., Silveira, C., Relvas, H., Duque, L., Roebeling, P. *et al.* (2016). A cost-efficiency and health benefit approach to improve urban air quality. *Science of the Total Environment* 569-570, 342-351. https://doi.org/10.1016/j.scitotenv.2016.06.102.

Mora, C., Tittensor, D.P., Adl, S., Simpson, A.G.B. and Worm, B. (2011). How many species are there on earth and in the ocean? *PLoS Biology* 9(8), e1001127. https://doi.org/10.1371/journal.pbio.1001127.

Organisation for Economic Co-operation and Development (2015). *Strengthening National Statistical Systems to Monitor Global Goals.* OECD and Post-2015 Reflections: Element 5, Paper 1. Paris. https://www.oecd.org/dac/POST-2015%20P21.pdf.

Overdevest, C., Orr, C.H. and Stepenuck, K. (2004). Volunteer stream monitoring and local participation in natural resource issues. *Human Ecology Review* 11(2), 177-185. https://www.humanecologyreview.org/pastissues/her112/overdevestorrstepenuck.pdf.

Pesaresi, M., Ehrlich, D., Kemper, T., Siragusa, A., Florczyk, A., Freire, S. *et al.* (2017). *Atlas of the Human Planet: Global Exposure to Natural Hazards.* European Union. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106292/atlas2017_online.pdf.

Prüss-Ustün, A., Wolf, J., Corvalán, C., Neville, T., Bos, R. and Neira, M. (2017). Diseases due to unhealthy environments: An updated estimate of the global burden of disease attributable to environmental determinants of health. *Journal of public health* 39(3), 464-475. https://doi.org/10.1093/pubmed/fdw085.

Salzmann, N., Huggel, C., Rohrer, M. and Stoffel, M. (2014). Data and knowledge gaps in glacier, snow and related runoff research – A climate change adaptation perspective. *Journal of Hydrology* 518, 225–234. https://doi.org/10.1016/j.jhydrol.2014.05.058.

Scheffers, B.R., Joppa, L.N., Pimm, S.L. and Laurance, W.F. (2012). What we know and don't know about Earth's missing biodiversity. *Trends in Ecology & Evolution* 27(9), 501-510. https://doi.org/10.1016/j.tree.2012.05.008.

Schulte-Uebbing, L., Hansen, G., Hernandez, A.M. and Winter, M. (2015). Chapter scientists in the IPCC AR5—experience and lessons learned. *Current Opinion in Environmental Sustainability* 14, 250-256. https://doi.org/10.1016/j.cosust.2015.06.012.

Seager, J. (2014). *Background and Methodology for Gender Global Environmental Outlook.* Nairobi: United Nations Environment Programme. https://web.unep.org/sites/default/files/ggeo/documents/GGEO_Multi-stakehoder_consultation_Background_document_final.pdf.

Siebenhüner, B. (2006). Administrator of global biodiversity: The secretariat of the convention on biological diversity. *Biodiversity and Conservation* 16(1), 259–274. https://doi.org/10.1007/s10531-006-9043-8.

Solow, R.M. (1974). Intergenerational equity and exhaustible resources. *The Review of Economic Studies* 41(5), 29-46. https://doi.org/10.2307/2296370.

Stevens, M., Vitos, M., Altenbuchner, J., Conquest, G., Lewis, J. and Haklay, M. (2014). Taking participatory citizen science to extremes. *IEEE Pervasive Computing* 13(2). https://doi.org/10.1109/MPRV.2014.37.

Stone, R. (1947). *Measurement of national income and the construction of social accounts: Report of the Sub-committee on National Income Statistics of the League of Nations Committee of Statistical Experts.* United Nations. http://www.worldcat.org/title/measurement-of-national-income-and-the-construction-of-social-accounts-report/oclc/610219052?referer=di&ht=edition.

Sustainable Development Solutions Network (2017). *Counting on the World: Building Modern Data Systems for Sustainable Development.* New York, NY. http://unsdsn.org/wp-content/uploads/2017/09/sdsn-trends-counting-on-the-world-1.pdf.

Sutherland, W.J., Gardner, T.A., Haider, L.J. and Dicks, L.V. (2014). How can local and traditional knowledge be effectively incorporated into international assessments? *Oryx* 48(1), 1-2. https://doi.org/10.1017/S0030605313001543.

Tengö, M., Malmer, P., Brondizio, E., Elmqvist, T. and Spierenburg, M. (2013). *The Multiple Evidence Base as a Framework for Connecting Diverse Knowledge Systems in the IPBES.* Stockholm: Stockholm Resilience Centre. http://www.stockholmresilience.org/download/18.416c425f13e06f977b11277/Multiple+Evidence+Base+for+IPBES+2013-06-05.pdf.

United Nations (1993). *Handbook of National Accounting: Integrated Environmental and Economic Accounting.* New York, NY. http://unstats.un.org/unsd/publication/SeriesF/SeriesF_61E.pdf.

United Nations (2012). *Addressing Inequalities: The Heart of the Post-2015 Agenda and the Future We Want for All.* http://www.un.org/millenniumgoals/pdf/Think%20Pieces/10_inequalities.pdf.

United Nations (2014). *System of Environmental-Economic Accounting 2012: Central Framework.* New York, NY. https://unstats.un.org/unsd/envaccounting/seearev/seea_cf_final_en.pdf.

United Nations, General Assembly (2015). *70/1. Transforming Our World: The 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly on 25 September 2015.* 21 October. A/RES/70/1. http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

United Nations (2015a). *The Millennium Development Goals Report.* New York, NY. http://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf.

United Nations (2015b). *World's Women 2015: Trends and Statistics.* https://unstats.un.org/unsd/gender/downloads/worldswomen2015_report.pdf.

United Nations (2016a). *World Economic and Social Survey 2014/2015.* New York, NY. http://www.un.org/en/development/desa/policy/wess/wess_archive/2015wess_full_en.pdf.

United Nations (2016b). *Sustainable Development Goals Report 2016.* New York, NY. http://unstats.un.org/sdgs/report/2016/.

United Nations (2016c). Geospatial information and earth observations: Supporting official statistics in monitoring the SDGs. *47th Session of the United Nations Statistical Commission Statistical-Geospatial Integration Forum.* New York, NY, 7 March. United Nations Statistical Commission https://www.fgdc.gov/organization/working-groups-subcommittees/unggim-wg/unggim-meeting-march-2016.pdf

United Nations (2017a). Report of the Inter-Secretariat Working Group on National Accounts: Supplement to the Report of the Inter-Secretariat Working Group on National Accounts. https://unstats.un.org/unsd/statcom/48th-session/documents/BG-NationalAccounts-Supplement-E.pdf

United Nations (2017b). *Report of the Inter-agency and Expert Group on Sustainable Development Goal Indicators.* https://unstats.un.org/unsd/statcom/48th-session/documents/2017-2-IAEG-SDGs-E.pdf.

United Nations (2018). *Tier Classification for Global SDG Indicators.* https://unstats.un.org/sdgs/files/Tier%20Classification%20of%20SDG%20Indicators_11%20May%202018_web.pdf.

United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development and World Bank (2003). *Handbook of National Accounting: Integrated Environmental and Economic Accounting 2003.* http://unstats.un.org/unsd/EconStatKB/Attachment60.aspx?AttachmentType=1.

United Nations Educational Scientific and Cultural Organization (2014). *Water and gender*. http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/water-and-gender/.

United Nations Educational Scientific and Cultural Organization (2015). *UNESCO Science Report: Towards 2030.* Institutions and Economies. Paris: United Nations Educational, Scientific and Cultural Organization. http://unesdoc.unesco.org/images/0023/002354/235406e.pdf.

United Nations Environment Programme (2012). *Global Environment Outlook-5: Environment for the Future We Want.* Nairobi. https://wedocs.unep.org/bitstream/handle/20.500.11822/8021/GEO5_report_full_en.pdf?isAllowed=y&sequence=5.

United Nations Environment Programme (2016). *Global Gender and Environment Outlook.* Nairobi. https://wedocs.unep.org/bitstream/handle/20.500.11822/14764/Gender_and_environment_outlook_HIGH_res.pdf?sequence=1&isAllowed=y.

https://doi.org/10.1017/9781108627146.009 Published online by Cambridge University Press

United Nations Environment Programme (2017). *Guidelines for Conducting Integrated Environmental Assessment* Nairobi. https://wedocs.unep.org/bitstream/handle/20.500.11822/16775/IEA_Guidelines_Living_Document_v2.pdf?sequence=1&isAllowed=y.

United States National Science Board (2016). Research and development: National trends and international comparisons. In Science *and Engineering Indicators*. Arlington, VA: National Science Foundation. chapter 4. https://www.nsf.gov/statistics/2016/nsb20161/uploads/1/7/chapter-4.pdf.

United States National Science Foundation (2017). *Federal funds for research and development*. http://www.nsf.gov/statistics/fedfunds/.

Vanoli, A. (2005). *National Accounting at the beginning of the 21st century: Where from? Where to?* European Commission. https://ec.europa.eu/eurostat/cros/system/files/p1-national_accounting_at_the_beginning_of_the_21st_century.pdf.

White, R. (ed.) (2017). *Transnational Environmental Crime*. London: Routledge. https://www.taylorfrancis.com/books/9781409447856.

World Bank (2002). *Building Statistical Capacity to Monitor Development Progress*. Washington, D.C. http://siteresources.worldbank.org/SCBINTRANET/Resources/Building_Statistical_Capacity_to_Monitor_Development_Progress.pdf.

World Health Organization (2018). *Global Health Observatory (GHO) Data: Mortality and Global Health Estimates*. http://www.who.int/gho/mortality_burden_disease/en/.

Yesson, C., Brewer, P.W., Sutton, T., Caithness, N., Pahwa, J.S., Burgess, M. *et al.* (2007). How global is the global biodiversity information facility? *PLoS ONE* 2(11), e1124. https://doi.org/10.1371/journal.pone.0001124.

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