Measuring Nature's Contribution to Economic Development

Towards a framework of indicators for national natural capital reporting

GGKP Expert Group on Natural Capital
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The Green Growth Knowledge Partnership (GGKP) is a global community of organizations and experts committed to collaboratively generating, managing and sharing green growth knowledge. Led by the Global Green Growth Institute (GGGI), Organisation for Economic Co-operation and Development (OECD), United Nations Environment Programme (UNEP), United Nations Industrial Development Organization (UNIDO) and the World Bank Group, the GGKP draws together over 60 partner organizations. For more information, visit www.greengrowthknowledge.org.

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The Green Growth Knowledge Partnership (GGKP) convenes inter-institutional expert groups to identify and address critical knowledge gaps in green growth theory and practice. The neutral, collaborative expert groups focus on knowledge generation, synthesis and on-the-ground application by partners and in-country stakeholders.

This report was prepared under the guidance of the GGKP Natural Capital Expert Group (hereinafter "Expert Group"). The Expert Group aims to push the knowledge frontier, mainstream natural capital in global green growth activities and support stronger implementation of natural capital commitments in national economic plans. In its deliberations, the group identified a key knowledge gap in the provision of a natural capital indicators framework to inform national green growth plans.

To clarify this gap and identify pathways to address it, the Expert Group, with support from the GGKP Secretariat, commissioned the University College London (UCL) to prepare this report. This publication was produced with Expert Group guidance and synthetic research by Alison Fairbrass (UCL), Georgina Mace (UCL), Paul Ekins (UCL) and Ben Milligan (University of New South Wales).

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SUMMARY

It is widely recognized that components of the environment are economic assets, termed natural capital, which are a foundation of social and economic development. Distinctive characteristics of natural capital are that some components renew and replenish themselves given appropriate management and that some components are not substitutable, and that benefits accrue from complex ecological and evolutionary systems operating across small to large spatial scales.

The 2030 Agenda for Sustainable Development and a growing range of commitments emphasize the need to account for and value natural capital in decision-making, for the purpose of more sustainable economic development planning, and more broadly. One factor that makes this difficult is the absence of a coherent framework of indicators concerning natural capital (and its benefits) that is fit for purpose for decision-making.

Here, we present an integrated Natural Capital Indicator Framework (NCIF), which provides a structure for countries to select and organize indicators to assess their use of and dependence on natural capital. The NCIF sits within a wider wealth creation framework composed of natural, human, social and manufactured capital. It is consistent with the conceptual framework and broad asset categories from the System of Environmental-Economic Accounting, and with the categories of flows from natural capital from the Common International Classification of Ecosystem Services. Where appropriate, it integrates indicators from the Sustainable Development Goals and other global initiatives related to sustainable development.

To meet international commitments concerning the social, economic, equity and environmental dimensions of sustainable development, countries must ensure that their economic performance is not dependent on unsustainable depletion of natural capital. The framework we present provides decision-makers with a manageable set of natural capital indicators with which to make decisions about economic development that take into account national natural capital and associated flows of benefits.

Keywords: accounting, assets, benefits, CICES, data, decision-making, economy, ecosystem services, environment, flows, GDP, indicators, information, natural capital, nature's contributions to people, policy, SEEA

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LIST OF ACRONYMS

CICES	Common International Classification of Ecosystem Services
CWI	Comprehensive Wealth Index
EROEI	Energy return on energy investment
GDP	Gross Domestic Product
GGGI	Global Green Growth Institute
GGKP	Green Growth Knowledge Partnership
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
IWI	United Nations' Inclusive Wealth Index
NCIF	Natural Capital Indicator Framework
NCI	Natural Capital Index
NCP	Nature's Contributions to People
OECD	Organization for Economic Co-operation and Development
SDG	Sustainable Development Goals
SEEA CF	UN System of Environmental-Economic Accounting – Central Framework
SEEA EEA	UN System of Environmental-Economic Accounting – Experimental Ecosystem Accounting
SNA	System of National Accounts
TEEB	The Economics of Ecosystems and Biodiversity
UCL	University College London
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
UNSD	United Nations Statistics Division
WAVES	World Bank's Wealth Accounting and the Valuation of Ecosystem Services

PROBLEM STATEMENT

There is a proliferation of datasets, tools and indicators, combined with the development of structured environmental-economic accounting, aimed at bringing some or all aspects of natural capital into economic decision-making. However, there is a lack of agreement on a standard set of natural capital indicators to inform decision-making, which hinders global efforts towards sustainable development. There is currently no overarching framework to guide countries in developing indicator sets to monitor natural capital and the contributions it provides to wealth and well-being. Each country will have its own context and unique needs, but the absence of such a framework complicates efforts to develop a comprehensive set of indicators to assess national dependence on natural capital in an internationally comparable manner. Decision-makers urgently need a manageable and coherent set of natural capital indicators to inform decisions about economic development.

NATURAL CAPITAL ACCOUNTING AND INDICATORS

There is an ongoing effort to develop structured concepts and accounting for relationships between the environment and the economy. Some of this effort is organized in terms of natural capital. Natural capital is another term for the stock of renewable and non-renewable natural resources on earth (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits or "services" to people *(1)*.

In the public sector, the System of Environmental-Economic Accounting – Central Framework (SEEA CF) *(2)*, and its related components of SEEA Water, SEEA Energy, and SEEA Agriculture, Forestry and Fisheries, provide a robust environmental accounting structure which integrates with national accounting systems via the System of National Accounts (SNA). This integration enables assessment of interrelationships between the economy and the environment, including the stocks and changes in stocks of certain commodity natural capital assets, and associated flows. The System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA EEA) *(3)* provides a similar structure for ecosystems and ecosystem service accounting.

The SEEA CF *(2)* and SEEA EEA *(3)* are contextualized by an "information pyramid" that seeks to bring organization and structure to the multiple sources of data and information involved in environmental economic accounting (Figure 1). Data and information sources are classified into four groups in a hierarchical structure with each layer of the pyramid feeding the layers above. Data and basic statistics are the foundation of the pyramid and support the accounting system. From the accounts are produced indicators, which can be aggregated to produce key indicators. Indicators can be sourced both directly from data and statistics, and from the accounts.

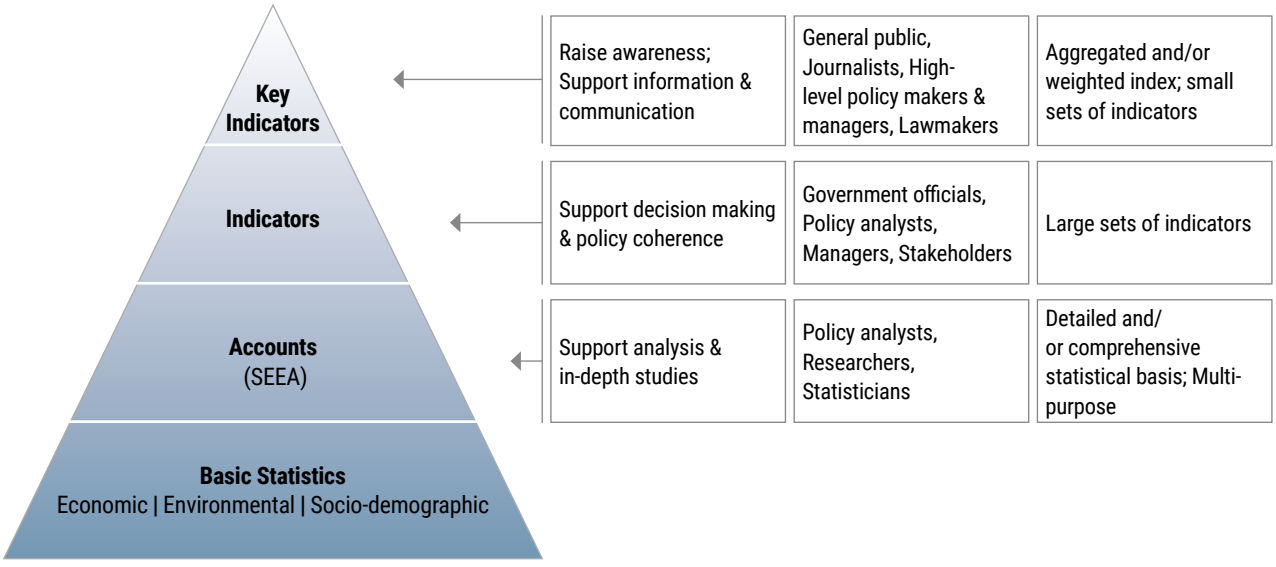

Figure 1. Information pyramid from UNSD 2013 *(4)*.

Indicators are an integral element of any system of quantifying the economy or the environment. They generally simplify in order to make complex phenomena quantifiable in such a manner that communication among different users or different contexts is either enabled or promoted. Indicators can capture the status of natural assets, such as the extent and condition of forests and water resources. They can also be used to quantify contributions of natural capital to the formal economy, such as the net value added of timber in the national accounts, and contributions to society at large, such as the percentage of the population with access to nutritious food and safe drinking water.

These benefits also depend on input of other forms of capital such as human, social and manufactured capital (Appendix 1). For example, human inputs (such as labour, tractors, fertilizer, or water pipes) are required to facilitate or increase the flow of benefits from natural assets to humans, and these can be captured through the use of integrated input-output tables in the national accounts and indicators derived from these. Finally, the residuals that are returned to the environment from the economy can be captured with indicators of emissions and waste production. Indicators are integral to the SNA and the SEEA, although a standard set of indicators for environmental accounting is not provided by SEEA. This has allowed countries flexibility in using indicators of their choice based on their needs and capabilities. However, this has also led to the use of a wide variety of indicators oriented towards particular purposes.

A brief example can illustrate the kinds of complexities and trade-offs that can arise when the exploitation of one ecosystem function leads to the loss of others. The provision of timber benefits from a clear-cut forest will be captured in the national accounts, as noted above, but it may also involve costs and foregone revenue flows due to ecosystem degradation, deforestation, the loss of natural infrastructure and non-timber forest products, and increased vulnerability to climate change. Climate change is making some economic production more difficult and reducing returns from some investments. Natural capital can reduce climate risks and help the economy to continue to provide for society. Thus natural capital can contribute to the economy through climate change mitigation (securing carbon sinks and continued provision of sequestration services) and adaptation (building resilient ecosystems to better withstand climate shocks and to help people adapt to new climate conditions). A natural capital indicator framework should be able to capture these trade-offs between the economic benefits registered in the national accounts (e.g. timber value added) and the ecosystem goods and services that may have been lost due to the timber extraction. The issues are complex, but for some communities the value of non-timber forest products may be larger than the extractive value of timber *(5)*.

The importance of natural capital to development and its sustainability is recognized in the 17 United Nations Sustainable Development Goals (SDGs) *(6)* and 169 associated Targets, which countries have committed to achieve by 2030. The SDG Target 17.19 calls for the development of "measurements of progress on sustainable development that complement GDP". This recognizes that, although GDP is the most popular and politically influential headline measure of economic progress, it gives only a partial picture of economic circumstances *(7,8)*. For example, it does not show when economic output is generated through unsustainable depletion of natural capital (domestically or abroad through imports). To take into account the values of nature, indicators of the stock of a nation's natural assets, and the flows of benefits that it produces, are required. This is often described as a natural capital approach.

There are ongoing efforts to develop natural capital indicators, typically within broader indicator frameworks of sustainability (e.g. SDGs *(6)*), national wealth (e.g. World Bank Changing Wealth of Nations *(9)*) and green growth (e.g. OECD Green Growth Indicators *(10)*). Although these indicator frameworks capture some of these components of natural capital, they tend to be limited in scope and to focus only on natural assets without including the full range of contributions derived from them, the human inputs required to co-produce these contributions and the residuals produced by their use.

The United Nations' Inclusive Wealth Index (IWI) assesses the changes in a nation's manufactured, human and natural capital as a complement to GDP *(7)*, which measures the flow of monetary income from that capital stock. Between 1990 and 2014 the IWI suggests that while the global stock of natural capital declined by 0.7%, global manufactured and human capital increased. The declining trend of natural capital in 123 out of the 140 countries assessed was masked by an increase in human and produced capital.

The Comprehensive Wealth Index (CWI) was used to assess the sustainability of Canada's economic growth and showed that despite robust GDP growth since 1980, Canada's market natural assets (minerals, fossil fuels, timber, agricultural land and built-up land) have declined by 17% from 1980 to 2015 as a result of depletion of many of Canada's natural resources *(11)*. In this case, Canada's Comprehensive Wealth was shown to have changed little over the period. Its growth of income was largely due to the depletion of its exhaustible resources, hardly a model of sustainable development. In this way, natural capital indicators can be used to complement more familiar economic indicators to show where natural capital is being depleted and to give a more comprehensive picture of a country's wealth profile.

In addition to environmental-economic accounting, a number of scientific assessments and initiatives have generated large volumes of biophysical data that seek to illuminate the interrelationships between the environment and the economy, and that often seek to quantify the monetary value and wider economic importance of natural capital. At the country scale, national assessments of ecosystems have given a monetary value to the benefits nations derive from the ecosystem services that flow from their natural assets. National ecosystem assessments have now been conducted in a number of countries including the UK *(12)*, Portugal *(13)*, Spain *(14)* and China *(15)*, all of which are based on the ecosystem services concept and have influenced the development of national policies on natural capital *(16)*.

Across Europe, countries are attempting the economic valuation of the ecosystem services flowing from their natural assets *(17)*. Outside Europe, many countries face data challenges to implement natural capital and environmental accounting. The World Bank's WAVES (Wealth Accounting and the Valuation of Ecosystem Services) partnership programme is working with a number of countries in Africa

(Botswana, Madagascar, Rwanda, Zambia), Asia (Indonesia, Philippines) and Latin America (Colombia, Costa Rica, Guatemala) to build capacity and see how such accounting can support sustainable development. The UN SEEA programme has a specific programme of training and workshops in Africa *(18)*. In addition, The Economics of Ecosystems and Biodiversity (TEEB) initiative supports countries in the valuation of natural capital *(19)*. The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) advocates for an inclusive approach to the valuation of nature that acknowledges different worldviews and diverse value systems *(20)*.

A number of tools have been developed in order to conduct integrated economic and environmental analysis *(21)*. Two of the more commonly used tools are InVest *(22)* and Co$ting Nature *(23)*. The InVest tool uses spatial data and production functions to estimate how changes in an ecosystem's structure and function are likely to affect the flows and values of ecosystem services. Different scenarios can be used to investigate the impact of different policy options, and the impacts of different scenarios are compared to inform decision-making. The Co$ting Nature tool uses spatial datasets from remote sensing and other global sources to model biophysical and socioeconomic processes, to calculate a baseline for ecosystem services anywhere globally. Similar to the InVest tool, it allows a series of interventions or scenarios of change to be modelled in order to assess their impact on ecosystem service provision. Using rapidly growing biophysical and economic datasets, these tools aim to inform decision-making on natural capital and ecosystem services.

Finally, the Natural Capital Protocol *(24)* provides a standardized framework for business to identify, measure and value their impacts and dependencies on natural capital. The protocol is focused at a business decision-making level and helps organizations to understand the value of their dependence on ecosystem flows, rather than the value of natural capital stocks.

Notwithstanding all this activity, there is currently a lack of agreement on a standard set of natural capital indicators to inform decision-making, which would support global efforts towards sustainable development.

THE CONCEPT OF CAPITAL

The concept of capital derives from economics, where it is used to signify any stock or asset from which a flow of benefits derives. In its narrowest interpretation capital is used to mean manufactured goods which themselves produce, or facilitate the production of, other goods and services. This kind of capital is referred to below as "manufactured capital".

The concept of capital has been extended in a number of directions, to take into account the quality (as well as the quantity) of labour (human capital), the networks through which labour is organized and which create the social context for economic activity (social/organizational capital), and the natural resources and environment which both provide inputs into the economic process and maintain the existence of life on earth (natural capital).

It is only gradually being understood in practical policy-making that natural capital is a foundational element of national wealth. Humans derive a wide range of benefits from the environmental assets that comprise natural capital, e.g. water from rivers, carbon storage and sequestration by coastal wetlands, and well-being impacts of nature-based recreation. The contributions that ecosystems make to human well-being have been termed "ecosystem services" *(25)*. This term has been widely adopted by scientists and policymakers, having been a major element of the Millennium Ecosystem Assessment *(26)*. An alternative conceptual perspective has been proposed in the form of Nature's Contributions to People (NCP), which extends beyond the ecosystem services concept by explicitly incorporating different worldviews on the human-nature relations and the way NCP are co-produced by nature and people *(27)*. In addition, non-ecosystem natural capital includes minerals, coal, oil, gas and water. These come from the abiotic environment and so fall outside the ecosystem services classification, although they are clearly part of natural capital.

For all forms of capital, the value of each asset is the present value of the services it provides and natural capital is no exception. In respect of natural capital, the services provided fall broadly into two groups: those that are already accounted for in the SNA and those that are not. For those that are in the SNA, the main task of valuation is one of attribution – what share of the value added is attributable to natural capital as opposed to other inputs that may have been involved in providing it, and what share should be attributed to the different natural capital assets that may have combined to produce them?

These are difficult and complex questions. There are a number of methods for eliciting this share, all of which have some problems, but based on them an estimate of this component of the value of natural capital can be derived. For those services provided outside the SNA, valuation needs to use one or a range of methods. It must also be mindful of the difference between the total value of the service, measured using willingness to pay or willingness to accept payment, and the marginal or exchange value, which is what the SNA data are based on. Both the World Bank and UNEP have constructed measures for different categories of natural capital, as noted below, addressing these problems as best they can. Uncertainties in the physical data are probably the most difficult issues in constructing meaningful measures.

A further important issue, detailed exploration of which is outside the scope of this paper, is the distribution of natural capital, and the benefits it provides, to different social groups. For example, it may be that a loss of natural capital may be of more social concern because of its impact on certain sections of society (particularly the poor in developing countries). Constructing a measure of the distribution of different forms of capital allows changes to be tracked not only in the stocks of different kinds of capital over time, but also in their distribution. This is where losses in natural capital can be most relevant: total capital may increase over time, but the gains in physical capital benefits are not distributed equally while the losses in natural capital can be concentrated among the poorer sections of society.

As noted above, natural capital is only one of a number of categories of capital stock. The World Bank's Changing Wealth of Nations *(9)* computes wealth in terms of produced capital and urban land, natural capital, human capital and net foreign assets, but also acknowledges the importance of social capital. The IWI has calculations for three categories of capital – manufactured, human and natural capital *(7)*. The Canadian CWI is based on a conceptual model that has five types of capital: produced capital, natural capital, human capital, social capital and financial capital *(11)*. Appendix 1 sets out a four-capitals framework together with a detailed explanation of how the stocks and flows interact.

A CONCEPTUAL FRAMEWORK FOR NATURAL CAPITAL

A conceptual framework for natural capital indicators should contain the key characteristics of the capital concept: stocks (assets), flows, human inputs, and outputs in the form of benefits and residuals. The shaded boxes in Figure A1 indicate the natural capital stocks and flows that are considered in this paper, which are elaborated further in Figure 2 . It can be seen that this is comprised of four connected components:

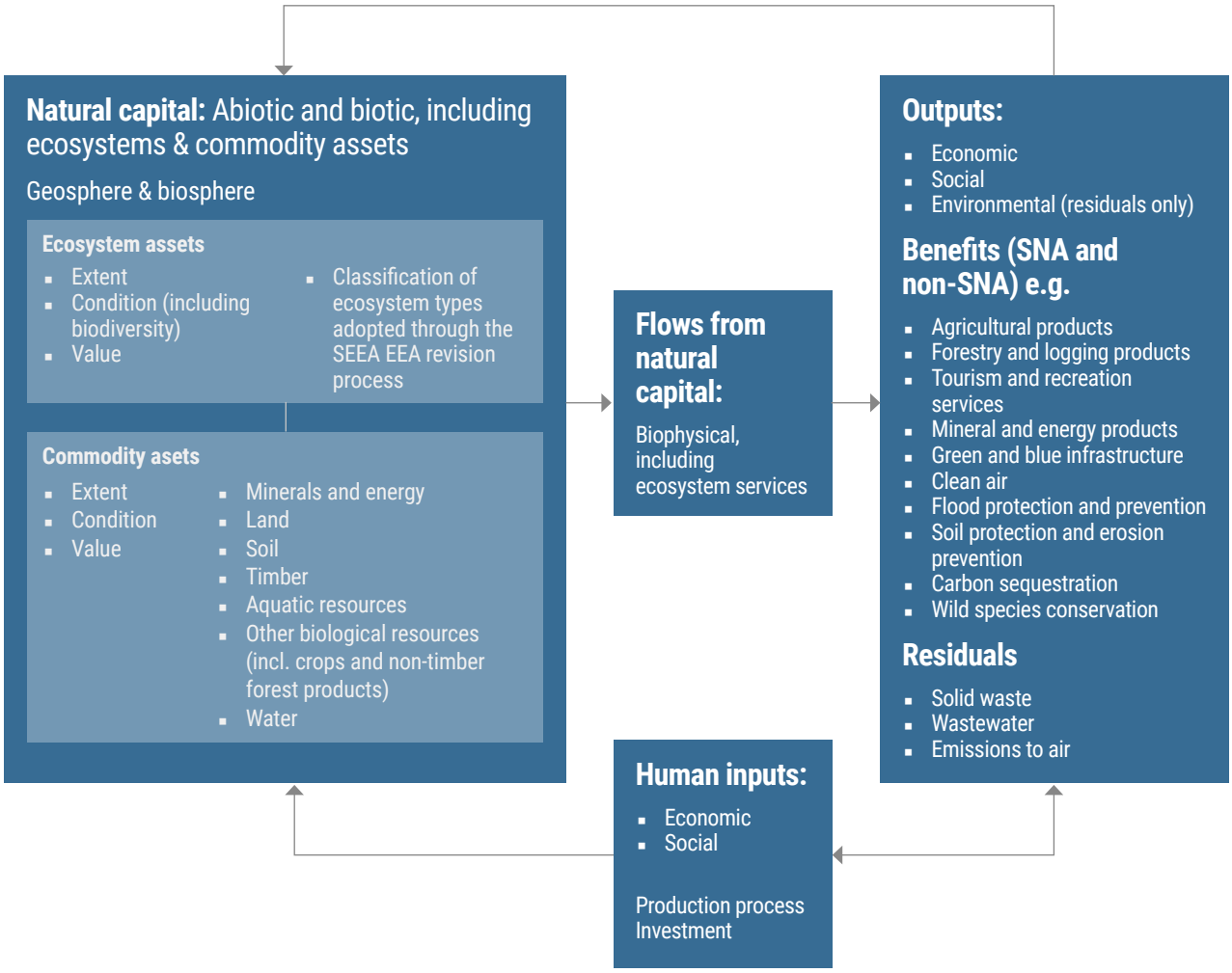

Figure 2. A conceptual framework for natural capital and the NCIF

NATURAL CAPITAL

The Earth system comprises the geosphere and biosphere, with the geosphere comprising the atmosphere, lithosphere, cryosphere and hydrosphere, and the biosphere containing all living matter that interacts with the geosphere. Natural capital may be biotic (living systems i.e. ecosystems, animal and plant life) or abiotic (non-living matter). Within the geosphere and biosphere are two kinds of assets: ecosystem assets (including terrestrial, marine and freshwater ecosystems, with both biotic and abiotic elements, which encompass the "dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" *(28)*), and commodity assets (the environmental assets, defined in the SEEA CF, the biotic components of which are produced by ecosystem assets, and the abiotic components of which are extracted from the geosphere).

The SEEA EEA does not define a classification of ecosystem types and this is a focus of the SEEA EEA Revision Process *(29)*. We will align the ecosystem assets component of the NCIF with the ecosystem typology that will eventually be adopted by the SEEA EEA. It must be noted that a comprehensive global-scale classification of ecosystems will be compli-

cated by the biogeographical differences among countries. There is a spatial/scaling problem (ecosystems can be overlapping at any scale) and a conceptual problem (ecosystems in different places may be functionally similar even if they are structurally quite different). It is more likely that ecosystem classification systems can be developed at the scale of countries and regions. The IUCN Red List of Ecosystems provides a methodology for classifying ecosystem types *(30)*.

Extent, condition and value indicators are prescribed for natural capital. Extent captures the area or quantity of each asset, condition captures the status of each asset which depends on the ecosystem service or services of interest (e.g. a good condition pasture for production may be poor for water quality), and value captures the economic value of the asset.

Accounting for biodiversity is important for several reasons that do not map neatly onto the natural capital framework *(31)*. Following the SEEA EEA, biodiversity is accounted for as part of the assessment both of ecosystem assets and of ecosystem condition.

Defining asset condition is important for both market and non-market ecosystem benefits and for biodiversity conservation. If the ecosystem assets are in worsening condition then the societal indicators (e.g. recreation, health, climate change resilience) and conservation benefits (fewer threatened and declining species) will show declines over time, even though other economic and social indicators might be improving. The changes in country accounts over time and the comparisons between countries should show these patterns.

Ecosystem condition metrics could include indicators of resilience. Biodiversity is often a predictor of resilience *(32)*. While there are separate thematic accounts for species in the SEEA EEA, for simplicity these are not included in the NCIF. How to account for biodiversity is a big focus of the revision of SEEA EEA that needs to be worked out and further developed. How this evolves may affect the NCIF in the future.

FLOWS FROM NATURAL CAPITAL

Natural capital flows include the widely understood concept of ecosystem services and our classification follows a standard system for their classification, the Common International Classification of Ecosystem Services (CICES) v.5.1 *(25)* classification of ecosystem services. Our rationale for using the flow terminology is that some users include the benefits that people receive within the definition of ecosystem services, while we are treating them as a different category in the framework because the benefits vary according to context and user, while flows vary with asset and asset management. Also, we intend to emphasize the distinction between assets (stocks) and flows (services).

In CICES, ecosystem services are defined as the contributions that ecosystems make to human well-being that depend on either biotic (living systems i.e. ecosystems and the biota in its broadest sense) or abiotic (non-living) parts of ecosystems, and are distinct from the goods and benefits that people subsequently derive from them, which aligns with the NCIF *(33)*. CICES is structured as a multilevel taxonomy of ecosystem services with six broad categories defined at the top level of this taxonomy: 1. Provisioning (Biotic), 2. Regulation and Maintenance (Biotic), 3. Cultural (Biotic), 4. Provisioning (Abiotic), 5. Regulation and Maintenance (Abiotic) and 6. Cultural (Abiotic). This upper level of the CICES classification system can be used as a broad initial checklist suitable for different contexts *(34)* and supplemented with the subsequent levels of the taxonomy when more detail on particular ecosystem services is desired, making it possible for countries to adapt the framework to their specific context. We use CICES for our categorization of the flows from natural capital rather than the IPBES NCP paradigm *(27)* or the Final Ecosystem Goods and Services Classification System *(35)* because the CICES is already acknowledged in the SEEA EEA with which we align to improve potential policy impact of the NCIF.

However, not all categories of flows are relevant to every ecosystem asset. Moreover, the flows are expressed in biophysical indicators to reflect the physical quantities of flows derived from ecosystem assets. Some flows are produced by more than one asset, and some assets produce or contribute to more than one type of flow. The flows only become benefits when they acquire value for people, when they can often be expressed in monetary terms. The complexity of the asset-flow-benefit causal stream, together with the difficulties in giving money values to non-market ecosystem goods and services, greatly increases the difficulties in valuing ecosystem assets in terms of the NPV of the flows and benefits to which they give rise. The NCIF described here does not go the extra step that is in the SEEA framework of seeking to express the benefits from natural capital in terms of their contribution to human welfare.

There is also the important question of whether there are thresholds in the levels of natural capital, sometimes called "critical natural capital" *(36)*, below which there is a dramatic decline of, or complete cessation in, the flow of services and benefits from that capital. It would be conceptually possible to include such thresholds in the NCIF, but determining them in practice is far from straightforward.

HUMAN INPUTS

Inputs from financial and other human activities (e.g. knowledge and labour) may interact with the ecosystem assets in order to produce the flows from natural capital which are then experienced as the benefits from ecosystem services *(3)*. The human inputs are expressed through economic and social indicators. Economic indicators focus on the costs associated with the human inputs required to connect ecosystem assets with benefits, while the principal social indicator associated with these human inputs is employment. The arrow from the human inputs component to the natural capital component of the NCIF indicates the relationship that human activities impact the state of natural capital. The reciprocal arrow between the human inputs component and the outputs component of the NCIF indicates that human inputs may be required to realize or further process the outputs from natural capital, while the outputs have effects on humans, positive in the case of benefits and usually negative in the case of residuals. Residuals can also have a (normally negative) impact on natural capital itself, as shown by the arrow across the top.

OUTPUTS

Outputs are organized into two broad categories: benefits derived from natural capital and residuals. In the context of ecosystem accounting, benefits comprise: a) the goods and services produced with human inputs as well as inputs from natural capital (e.g. food, water, clothing, shelter, recreation). These are referred to as SNA benefits, since the measurement boundary is defined by the production boundary used to measure GDP in the SNA. This includes goods produced from natural capital by households for their own consumption; b) the benefits that accrue to individuals that are not produced with human inputs (e.g. clean air, flood protection from mangrove forests or coral reefs). These benefits are referred to as non-SNA benefits, reflecting the fact that the receipt of these benefits by individuals is not the result of an economic production process defined within the SNA.

These two types of benefits may be distinguished by the fact that, in general, SNA benefits have the potential to be bought and sold on markets whereas non-SNA benefits do not *(3)*. It is important to recognize the difference between benefits and the bio-physical flows from which they are derived. The flows are bio-physical facts resulting from natural capital (e.g. flowing streams, reproduction of fish), but they only become benefits when they deliver value to people, where this value is often expressed in monetary terms. Thus, all fish stocks produce flows of fish. But only those flows of fish which give value to people are classed as benefits (while recognizing that the fish may be delivering biodiversity and other ecosystem benefits and not just benefits from consumption).

Residuals comprise the flows of solid, liquid and gaseous materials, and energy that are discarded, discharged or emitted by establishments and households through processes of production, consumption or accumulation *(2)*. Benefits are assessed using economic and social indicators. Economic indicators focus on the contribution of benefits to the economy, such as the value added to the national accounts, value associated with avoided health costs and value of mitigated damages from natural disasters. Social indicators focus on the social impacts of benefits, such as access to clean water. Residuals are assessed using economic, environmental and social indicators. Economic indicators focus on the costs of processing residuals or the damages caused by them, environmental indicators focus on volumes of residuals, and social indicators focus on the social impacts of residuals, such as the percentage of a population exposed to dangerous levels of air pollution. The arrow to the outputs component from the flows from natural capital component of the NCIF indicates the relationship that outputs are derived from natural capital flows.

As an example of the various interactions, consider a human input in the form of investment in agroforestry techniques, with intercropping. This would protect the natural asset of soil, and perhaps enhance its fertility, while producing ecosystem services of timber, fodder, food, water retention and soil carbon sequestration, i.e. it would produce a variety of flows from the natural capital, which would in turn be reflected in SNA and non-SNA benefits.

This conceptual framework in Figure 2 has several noteworthy points of contrast with recent literature, in particular with the natural capital asset classification recently presented by Leach *et al.* (2019) *(37)*. The major points of contrast are:

- Unlike Leach *et al.* (2019), Figure 2 makes no clear distinction between biotic and abiotic assets. The classification here is based on the definable flows of services and benefits into the economy – this corresponds to the definition of capital. It is also necessary to have interacting biotic and abiotic components in asset classes in order that they deliver their functional roles, for example natural capital assets (e.g. soil, ecosystems) have mixed biotic and abiotic elements.
- Again unlike Leach *et al.* (2019), the NCIF in Figure 2 treats biodiversity as a characteristic of all ecosystems, which are in the top level of natural capital, rather than as a distinct asset, as in the Leach *et al.* paper. Biodiversity is a key indicator of ecosystem asset quality in the NCIF. Clearly the flows from natural capital, and the benefits they result in, are dependent on the characteristics of ecosystems, including biodiversity, although the relationships and roles of the different characteristics in producing the flows are complex.
- Finally, Figure 2 identifies the flows from and benefits of natural capital as core parts of the natural capital indicator framework, whereas in Leach *et al.* they appear as isolated case study examples. Yet it is the flows and benefits that actually distinguish natural capital from environmental components of no economic interest. This is important because it is the trend in the flows and benefits from natural capital that are relevant to questions as to whether the natural capital is being used sustainably or not, if necessary reflecting lags and thresholds between asset condition, flows and benefits

The framework outlined in Figure 2 is consistent with and complementary to a number of existing indicator frameworks. The OECD's Green Growth Indicators framework *(10)* and the Natural Capital section of the World Bank's Changing Wealth of Nations framework *(9)* both focus on natural capital assets, with the World Bank having a stronger focus on natural resource use and the OECD having a more holistic framework that includes biodiversity. Our framework could be used to extend these natural asset focused frameworks to include flows, human inputs and outputs. Neither framework includes indicators of ecosystems. Both are also limited in terms of how they capture the marine environment. Integration with our framework would fill these gaps.

The Natural Capital Index (NCI) currently under construction by the World Bank and the Natural Capital Project *(38)* takes a different approach by seeking to construct a "production possibility frontier" from a country's natural capital, incorporating ecosystem services, measured in monetary terms, human health impacts and a biodiversity measure. The NCI would therefore permit comparisons between countries on the basis of their efficiency in making use of their natural capital endowments.

A different approach again to indicators of natural capital is taken by IPBES with their framework built around the NCP concept *(39)*, which focuses on flows and benefits to people rather than assets. Notwithstanding this focus, the current set of indicators populating the NCP indicator framework are predominantly focused on assets, dominated by indicators of asset state such as land cover extent and marine stocks. If the ecosystem services concept and associated service classifications (e.g. CICES) are considered too narrow and specific about the nature of services, our framework could be adapted using the IPBES NCP concept which focusses more on benefits. The Stockholm Resilience Centre has developed an indicator framework based on the SDGs and the concept of planetary boundaries *(40)* which is a broader approach within which our proposal could be used for reporting. While their indicators are very broad rather than comprehensive, e.g. the suggested indicator for SDG 14 Life below water is "Acidity of ocean surface water (pH)", our framework is consistent with the concept of planetary boundaries; for example, by developing thresholds of critical natural capital within global goals and boundaries.

These different approaches to indicators of natural capital show the importance of clarity over the purpose of the indicators, and what situations or conditions they are intended to generate insights about. The NCIF presented here comprises a framework which can incorporate the full range of a country's natural capital assets, the biophysical flows from those capital assets, the human inputs which may have co-produced these biophysical flows, the benefits deriving from those flows, and the physical residuals from them. The whole framework is entirely consistent with SEEA and the emerging treatment of ecosystems within it.

There remains uncertainty about how biodiversity should be included in ecosystem accounts *(41)*. This is mostly because biodiversity is such a broad term and is often used vaguely for assets, services and benefits. However, if biodiversity components are clarified then it is clearly either an asset or a benefit (and sometimes a service itself) *(31,42)*. In our framework, we include biodiversity as a measure of ecosystem asset condition. The conservation of wild species is also included as a benefit. To achieve this benefit, we need to see both the diversity (number of species) and abundance of wild species at least being maintained and sometimes increasing. Therefore, indicators of species abundance (Living Planet Index *(43)*) and diversity (Red List Index *(44)*) are also included as flows within the framework.

SUGGESTIONS FOR NATURAL CAPITAL INDICATORS

Here we present suggestions for natural capital indicators based on the conceptual framework in Figure 2 in order to enable national governments to monitor the state, condition and value of their natural capital. The purpose of the indicators is to:

1. Provide public policy-makers with summary information about the state, condition and value of natural capital assets and associated flows from natural capital and the benefits these flows deliver;
2. Provide a set of indicators for natural capital that can operate as a front-end for a system of environmental economic accounting such as SEEA; and
3. Assess if development is occurring sustainably.

We hope that the framework will show how important defining asset condition is for both market and non-market ecosystem benefits and for biodiversity conservation. If the ecosystem assets are in poor condition then the societal indicators (e.g. recreation, climate change resilience) and conservation benefits (fewer threatened and declining species) will show declines over time while other indicators might be increasing. The changes in country accounts over time and the comparisons between countries should show these patterns.

We suggest indicators to populate the framework in Tables 1-4 according to the classification of Figure 2, comprising indicators of natural capital, flows from natural capital, human inputs into natural capital, and outputs from natural capital including benefits from natural capital and residuals that may affect natural capital or the benefits derived from it. These indicators may be compared with indicators from scientific literature on indicators and other global indicator initiatives such as those associated with the SDGs and Aichi Targets. Relevant indicators from the scientific literature and international indicator initiatives are presented, in the same classification of Figure 2, in Tables A1, A2, A3 and A4. Where appropriate, using the same indicators for multiple initiatives/commitments is clearly desirable as it reduces the burden on countries of data collection and processing.

It may be noted that there is a lag in the integration of flow indicators into existing accounting and indicator frameworks. The SEEA EEA ecosystem service accounts do not align with many existing global indicator initiatives, and are generally associated with very conventional provisioning ecosystem services (biomass, crop, fisheries and wood provision) *(45)*. Existing indicator frameworks, such as the SDGs, do not capture ecosystem service flows well and therefore the flow component of our framework does not contain any indicators from such initiatives. A large number of flow indicators exist which tend to focus on specific physical phenomena, such as soil decomposition rate *(46)*. However, there is clearly a gap between the scientific development of flow indicators and their application in accounting and indicator frameworks. It is hoped that the framework presented here can provide guidance on the integration of flow indicators into existing more asset-focused accounting and indicator frameworks.

INDICATOR TABLES

The following Tables 1-4 follow the conceptual framework set out in Figure 2 (reproduced below for convenience).

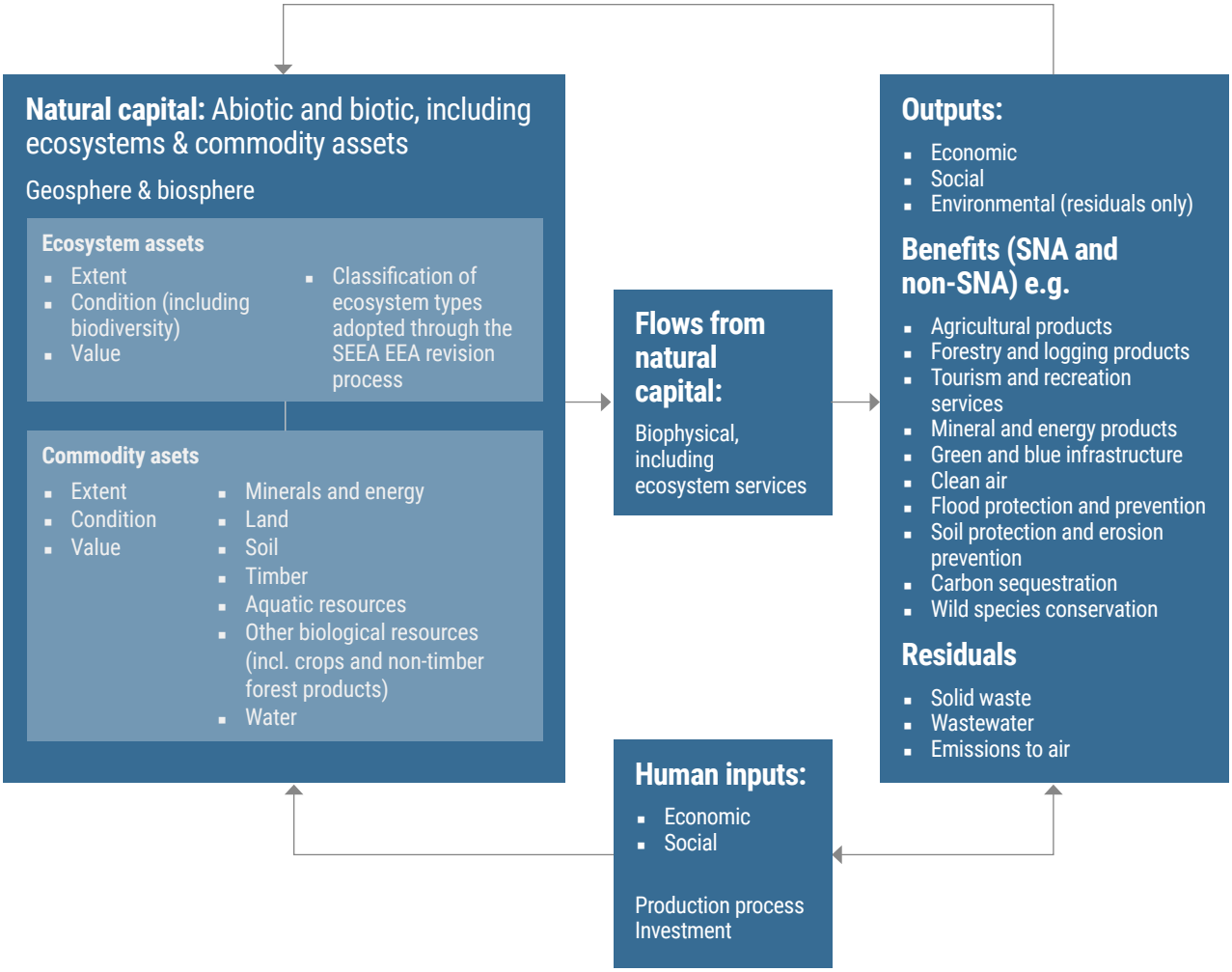

Table 1. Commodity and ecosystem asset indicators.

Illustrative generic terrestrial, freshwater and marine ecosystem asset indicators (8.1-8.3) are provided pending the development of a typology of ecosystem assets through the SEEA EEA Revision Process. For comparison or alternative selection Table A1 presents in the same classification other relevant indicators from other international indicator initiatives.

Asset type	Quantity	Quality	Value
Commodity assets			
1. Mineral and energy resources	Reserves-to-production ratio; reserves	Energy return on energy investment (EROEI) (mJ/t)	Net present value of mineral and energy reserves ($)
1.1. Oil resources	Reserves-to-production ratio; reserves	Energy return on energy investment (EROEI) (mJ/t)	Net present value of oil reserves ($)
1.2. Natural gas resources	Reserves-to-production ratio; reserves	Energy return on energy investment (EROEI) (mJ/t)	Net present value of natural gas reserves ($)
1.3. Coal and peat resources	Reserves-to-production ratio; reserves	Energy return on energy investment (EROEI) (mJ/t)	Net present value of coal and peat reserves ($)
1.4. Non-metallic mineral resources (excluding coal and peat resources)	Reserves-to-production ratio; reserves	Energy intensity of extraction (mJ/t)	Net present value of non-metallic mineral reserves (excluding coal and peat reserves) ($)
1.5. Metallic mineral resources	Reserves-to-production ratio; reserves	Energy intensity of extraction (mJ/t)	Net present value of metallic mineral reserves ($)

Asset type	Quantity	Quality	Value
2. Land	Area of different types of land use including cropland, pastureland, forest and urban (ha); area of degraded land (ha)	Indicator of land degradation	?
3. Soil resources	Volume/area of soil stock (ha/m3)	Soil organic matter content; soil pH; soil carbon	Net present value of soil resources ($)
4. Timber resources	Area of timber resources (ha)	Wood quality indicator	Net present value of timber resources ($)
4.1. Cultivated timber resources	Area of cultivated timber resources (ha)		Net present value of cultivated timber resources ($)
4.2. Natural timber resources	Area of natural timber resources (ha)		Net present value of natural timber resources ($)
5. Aquatic resources	Area of freshwater and marine environment (ha)	Fisheries Stock Performance Indicator	Net present value of aquatic resources ($)
5.1. Cultivated aquatic resources	Area of cultivated freshwater and marine environment (ha)	Cultivated Fisheries Stock Performance Indicator	Net present value of cultivated aquatic resources ($)
5.2. Natural aquatic resources	Area of natural freshwater and marine environment (ha)	Natural Fisheries Stock Performance Indicator	Net present value of natural aquatic resources ($)
6. Other biological resources	Area of land for cultivation of animals and plants (ha)	Productivity of cultivated animal and plant industries; an indicator of sustainable agriculture	Net present value of other biological resources ($)
7. Water resources	Available renewable water resources (l)	Water Quality Index for Biodiversity	Net present value of water resources ($)
7.1. Surface water	Available renewable surface water resources (l)	Water Quality Index for Biodiversity	Net present value of surface water ($)
7.2. Groundwater	Available renewable groundwater resources (l)	Water Quality Index for Biodiversity	Net present value of groundwater ($)
7.3. Soil water	Available renewable soil water resources (l)	Water Quality Index for Biodiversity	Net present value of soil water ($)
Ecosystem assets			
8. Ecosystems and conditions	Aggregate area of ecosystem assets (ha)	Biodiversity Intactness Index for all ecosystems	Net present value of ecosystem assets ($)
8.1. Ecosystem type (Terrestrial)	Area of terrestrial ecosystem assets (ha)	Biodiversity Intactness Index for terrestrial ecosystem assets	Net present value of terrestrial ecosystem assets
8.2. Ecosystem type (Freshwater and Wetlands)	Area/volume of freshwater ecosystem assets (ha/m3)	Biodiversity Intactness Index for freshwater ecosystem assets	Net present value of freshwater and wetlands ecosystem assets ($)
8.3. Ecosystem type (Marine)	Area/volume of marine ecosystem assets (ha/m3)	Biodiversity Intactness Index for marine ecosystem assets	Net present value of marine ecosystem assets ($)

Table 2. Flow indicators for commodity and ecosystem assets.

Types of ecosystem services flows are indicated by P (Provisioning), R&M (Regulation & Maintenance), C (Cultural), B (Biotic) and A (Abiotic) following the Common International Classification of Ecosystem Services *(25)*. Illustrative generic terrestrial, freshwater and marine ecosystem asset indicators (8.1-8.3) are provided pending the development of a typology of ecosystem assets through the SEEA EEA Revision Process. For comparison or alternative selection Table A2 presents in the same classification other relevant indicators from other international indicator initiatives.

Asset type	Biophysical
Commodity assets	
1. Mineral and energy resources	P (A): Volume extracted (tonnes)
1.1. Oil resources	P (A): Volume extracted (gallons)
1.2. Natural gas resources	P (A): Volume extracted (gallons)
1.3. Coal and peat resources	P (A): Volume extracted (tonnes)
1.4. Non-metallic mineral resources (excluding coal and peat resources)	P (A): Volume extracted (tonnes)
1.5. Metallic mineral resources	P (A): Volume extracted (tonnes)
2. Land	P (A/B): Change in area of different types of land use including cropland, pastureland, forest and urban (ha)
3. Soil resources	R&M (B): ?
4. Timber resources	P (B): Volume harvested (tonnes)
4.1. Cultivated timber resources	P (B): Volume harvested (tonnes)
4.2. Natural timber resources	P (B): Volume harvested (tonnes)
5. Aquatic resources	P (B): Volume harvested (tonnes)
5.1. Cultivated aquatic resources	P (B): Volume harvested (tonnes)
5.2. Natural aquatic resources	P (B): Volume harvested (tonnes)
6. Other biological resources	P (B): Volume harvested (tonnes)
7. Water resources	P (A): Volume abstracted (l)
7.1. Surface water	P (A): Volume abstracted (l)
7.2. Groundwater	P (A): Volume abstracted (l)
7.3. Soil water	P (A): Volume abstracted (l)

Asset type	Biophysical
Ecosystem assets	
8. Ecosystems and conditions	P (B): Volume of wild plants and animals harvested for nutrition and genetic material from ecosystems (tonnes) R&M (B): Living Planet Index C (B): Red List Index P (A): Volume of water harvested for drinking, non-drinking and energy purposes, and mineral and non-mineral substances or ecosystem properties harvested for nutritional, material and energy purposes from ecosystems (l and tonnes) R&M (A): NA C (A): ?
8.1. Ecosystem type (Terrestrial)	P (B): Volume of wild plants and animals harvested for nutrition and genetic material from terrestrial ecosystem assets (tonnes) R&M (B): Living Planet Index for terrestrial ecosystem assets C (B): Red List Index for terrestrial ecosystem assets P (A): Volume of mineral and non-mineral substances or ecosystem properties harvested for nutritional, material and energy purposes from terrestrial ecosystem assets (tonnes) R&M (A): NA C (A): ?
8.2. Ecosystem type (Freshwater and Wetlands)	P (B): Volume of wild plants and animals harvested for nutrition and genetic material from freshwater ecosystem assets (tonnes) R&M (B): Living Planet Index for freshwater ecosystem assets C (B): Red List Index for freshwater ecosystem assets P (A): Volume of water harvested for drinking, non-drinking and energy purposes, and mineral and non-mineral substances or ecosystem properties harvested for nutritional, material and energy purposes from freshwater ecosystem assets (l and tonnes) R&M (A): NA C (A): ?
8.3. Ecosystem type (Marine)	P (B): Volume of wild plants and animals harvested for nutrition and genetic material from marine ecosystem assets (tonnes) R&M (B): Living Planet Index for marine ecosystem assets C (B): Red List Index for marine ecosystem assets P (A): Volume of water harvested for drinking, non-drinking and energy purposes, and mineral and non-mineral substances or ecosystem properties harvested for nutritional, material and energy purposes from marine ecosystem assets (l and tonnes) R&M (A): NA C (A): ?

Table 3. Human inputs indicators for commodity and ecosystem assets.

Illustrative generic terrestrial, freshwater and marine ecosystem asset indicators (8.1-8.3) are provided pending the development of a typology of ecosystem assets through the SEEA EEA Revision Process. For comparison or alternative selection Table A3 presents in the same classification other relevant indicators from other international indicator initiatives.

Asset type	Economic	Social
Commodity assets		
1. Mineral and energy resources	Total cost of extraction ($)	Proportion of total employment in relevant industry
1.1. Oil resources	Cost of extraction ($)	Proportion of total employment in relevant industry
1.2. Natural gas resources	Cost of extraction ($)	Proportion of total employment in relevant industry
1.3. Coal and peat resources	Cost of extraction ($)	Proportion of total employment in relevant industry
1.4. Non-metallic mineral resources (excluding coal and peat resources)	Cost of extraction ($)	Proportion of total employment in relevant industry
1.5. Metallic mineral resources	Cost of extraction ($)	Proportion of total employment in relevant industry
2. Land	?	Proportion of total employment in relevant industry
3. Soil resources	Expenditure in managing soil erosion ($)	Proportion of total employment in relevant industry
4. Timber resources	Total cost of harvesting timber ($)	Proportion of total employment in relevant industry
4.1. Cultivated timber resources	Cost of harvesting cultivated timber ($)	Proportion of total employment in relevant industry
4.2. Natural timber resources	Cost of harvesting natural timber ($)	Proportion of total employment in relevant industry
5. Aquatic resources	Total costs of harvesting aquatic resources ($)	Proportion of total employment in relevant industry
5.1. Cultivated aquatic resources	Cost of harvesting cultivated aquatic resources ($)	Proportion of total employment in relevant industry
5.2. Natural aquatic resources	Cost of harvesting natural aquatic resources ($)	Proportion of total employment in relevant industry
6. Other biological resources	Cost of inputs into harvesting cultivated animals and plants and natural biological resources ($)	Proportion of total employment in relevant industry
7. Water resources	Total cost of water abstraction ($)	Proportion of total employment in relevant industry
7.1. Surface water	Cost of surface water abstraction ($)	Proportion of total employment in relevant industry
7.2. Groundwater	Cost of groundwater abstraction ($)	Proportion of total employment in relevant industry
7.3. Soil water	Cost of soil water abstraction ($)	Proportion of total employment in relevant industry

Asset type	Economic	Social
Ecosystem assets		
8. Ecosystems and conditions	Costs of management of all ecosystem assets ($)	Proportion of total employment in relevant industry
8.1. Ecosystem type (Terrestrial)	Cost of managing terrestrial ecosystem assets ($)	Proportion of total employment in relevant industry
8.2. Ecosystem type (Freshwater and Wetlands)	Cost of managing freshwater ecosystem assets ($)	Proportion of total employment in relevant industry
8.3. Ecosystem type (Marine)	Cost of managing marine ecosystem assets ($)	Proportion of total employment in relevant industry

Table 4. Output indicators for benefits and residuals.

Types of ecosystem services flows are indicated by P (Provisioning), R&M (Regulation & Maintenance), C (Cultural), B (Biotic) and A (Abiotic) following the Common International Classification of Ecosystem Services *(25)*. Illustrative generic terrestrial, freshwater and marine ecosystem asset indicators (8.1-8.3) are provided pending the development of a typology of ecosystem assets through the SEEA EEA Revision Process. For comparison or alternative selection Table A4 presents in the same classification other relevant indicators from other international indicator initiatives.

Asset/Residual type	Economic	Social	Environmental
Benefits			
Commodity assets			
1. Mineral and energy resources	P (A): Gross value added in the National Accounts associated with all mineral and energy resources ($)	P (A): ?	NA
1.1. Oil resources	P (A): Gross value added in the National Accounts associated with oil resources ($)	P (A): ?	NA
1.2. Natural gas resources	P (A): Gross value added in the National Accounts associated with natural gas resources ($)	P (A): ?	NA
1.3. Coal and peat resources	P (A): Gross value added in the National Accounts associated with coal and peat resources ($)	P (A): ?	NA
1.4. Non-metallic mineral resources (excluding coal and peat resources)	P (A): Gross value added in the National Accounts associated with non-metallic mineral resources ($)	P (A): ?	NA
1.5. 1.5 Metallic mineral resources	P (A): Gross value added in the National Accounts associated with metallic mineral resources ($)	P (A): ?	NA
2. Land	P (A/B): Land rents ($)	?	NA
3. Soil resources	R&M (B): ?	R&M (B): ?	NA
4. Timber resources	P (B): Gross value added in the National Accounts associated with all timber ($)	P (B):	NA
4.1. Cultivated timber resources	P (B): Gross value added in the National Accounts associated with cultivated timber resources ($)	P (B):	NA

Asset/Residual type	Economic	Social	Environmental
4.2. Natural timber resources	P (B): Gross value added in the National Accounts associated with natural timber resources ($)	P (B):	NA
5. Aquatic resources	P (B): Gross value added in the National Accounts associated with all aquatic resources ($)	P (B): Proportion of population with access to aquatic resources	NA
5.1. Cultivated aquatic resources	P (B): Gross value added in the National Accounts associated with cultivated aquatic resources ($)	P (B): ?	NA
5.2. Natural aquatic resources	P (B): Gross value added in the National Accounts associated with natural aquatic resources ($)	P (B): ?	NA
6. Other biological resources	P (B): Gross value added in the National Accounts associated with cultivated animals and plants ($)	P (B): Fraction of population undernourished (%)	NA
7. Water resources	R&M (B): Costs of water related damage (floods, coastal damage) ($) P (A): Gross value added in the National Accounts associated with water for drinking, non-drinking and energy purposes ($) R&M (A): ?	R&M (B): Proportion of population affected by water-related events P (A): Fraction of population with access to safe water (%) R&M (A): Fraction of population exposed to water pollution (%)	NA
7.1. Surface water	Ditto	Ditto	NA
7.2. Groundwater	Ditto	Ditto	NA
7.3. Soil water	Ditto	Ditto	NA
Ecosystem assets			
8. Ecosystems and conditions	P (B): Gross value added in the National Accounts associated wild plants and animals for nutrition and genetic material harvested from all ecosystems ($) R&M (B): Gross value added in the National Accounts associated with health impacts associated with ecosystems ($) C (B): Gross value added to National Accounts of ecosystem-related tourism ($) P (A): Gross value added to National Accounts by water for drinking, non-drinking and energy purposes, and mineral and non-mineral substances or ecosystem properties for nutritional, material and energy purposes from all ecosystems ($) R&M (A): Gross value added in the National Accounts of disaster mitigation associated with all ecosystems ($) C (A): Value of jewelry market ($)	P (B): Proportion of population that harvest wild plants and animals for nutrition from ecosystems R&M (B): Proportion of population using ecosystems for exercise/ health reasons C (B): Proportion of population who are members of biodiversity conservation organizations P (A): Proportion of population with access to water for drinking, non-drinking and energy purposes, and mineral and non-mineral substances or ecosystem properties for nutritional, material and energy purposes from all ecosystems R&M (A): Number of disaster-related avoided deaths attributed to all ecosystems C (A): ?	NA

Asset/Residual type	Economic	Social	Environmental
8.1. Ecosystem type (Terrestrial)	P (B): Gross value added in the National Accounts associated wild plants and animals for nutrition and genetic material harvested from relevant ecosystem ($) R&M (B): Gross value added in the National Accounts associated with health impacts associated with relevant ecosystem ($) C (B/A): Gross value added to National Accounts of tourism associated with the relevant ecosystem ($) P (A): Gross value added to National Accounts by water for drinking, non-drinking and energy purposes, and mineral and non-mineral substances or ecosystem properties for nutritional, material and energy purposes from relevant ecosystem ($) R&M (A): Gross value added in the National Accounts of disaster mitigation associated with relevant ecosystem ($)	P (B): Proportion of population that harvest wild plants and animals for nutrition from relevant ecosystem R&M (B): Proportion of population using relevant ecosystems for exercise/health reasons C (B): Proportion of population who are members of biodiversity conservation organizations P (A): Proportion of population with access to water for drinking, non-drinking and energy purposes, and mineral and non-mineral substances or ecosystem properties for nutritional, material and energy purposes from relevant ecosystem R&M (A): Number of disaster-related avoided deaths attributed to relevant ecosystem C (A): ?	NA
8.2. Ecosystem type (Freshwater and Wetlands)	P (B): Gross value added in the National Accounts associated wild plants and animals for nutrition and genetic material harvested from relevant ecosystem ($) R&M (B): Gross value added in the National Accounts associated with health impacts associated with relevant ecosystem ($) C (B/A): Gross value added to National Accounts of tourism associated with the relevant ecosystem ($) P (A): Gross value added to National Accounts by water for drinking, non-drinking and energy purposes, and mineral and non-mineral substances or ecosystem properties for nutritional, material and energy purposes from relevant ecosystem ($) R&M (A): ?	P (B): Proportion of population that harvest wild plants and animals for nutrition from relevant ecosystem R&M (B): Proportion of population using relevant ecosystems for exercise/health reasons C (B): Proportion of population who are members of biodiversity conservation organizations P (A): Proportion of population with access to water for drinking, non-drinking and energy purposes, and mineral and non-mineral substances or ecosystem properties for nutritional, material and energy purposes from relevant ecosystem R&M (A): Fraction of population exposed to freshwater pollution (%) C (A): ?	NA

Asset/Residual type	Economic	Social	Environmental
8.3. Ecosystem type (Marine)	P (B): Gross value added in the National Accounts associated wild plants and animals for nutrition and genetic material harvested from relevant ecosystem ($) R&M (B): Gross value added in the National Accounts associated with health impacts associated with relevant ecosystem ($) C (B/A): Gross value added to National Accounts of tourism associated with the relevant ecosystem ($) P (A): Gross value added to National Accounts by water for drinking, non-drinking and energy purposes, and mineral and non-mineral substances or ecosystem properties for nutritional, material and energy purposes from relevant ecosystem ($) R&M (A): ?	P (B): Proportion of population that harvest wild plants and animals for nutrition from relevant ecosystem R&M (B): Proportion of population using relevant ecosystems for exercise/health reasons C (B): Proportion of population who are members of biodiversity conservation organizations P (A): Proportion of population with access to water for drinking, non-drinking and energy purposes, and mineral and non-mineral substances or ecosystem properties for nutritional, material and energy purposes from relevant ecosystem R&M (A): Fraction of population exposed to marine pollution (%) C (A): ?	NA
Residuals			
Solid waste	Cost of solid waste treatment ($)	Volume of waste managed by management type (tonnes)	Employment in waste management by management type
Waste water	Cost of waste water treatment ($)	Volume of waste water managed to regulated quality (l)	Employment in waste water industry
Emissions to air	1. Carbon market value ($) 2. Damages from stratospheric ozone depletion ($) 3. Damages from local air pollution ($)	1. GHG emissions (tonnes) 2. Emissions of ozone-depleting substances (tonnes) 3. Other air emissions (selection) (tonnes)	1. Population affected by climate-related disasters 2. Population affected by ozone depletion 3. Population exposure to local air pollution
Emissions to land	Environmental costs of disposal of waste, toxics and other nuisances to land ($)	Volume of disposal to landfill or littering or dumping (tonnes)	Health indicator related to landfill
Emissions to water	Environmental costs of disposal of waste, toxics and other nuisances in marine and freshwater environments ($)	Volume of waste water untreated (l) and disposed of to marine and freshwater environments Hazardous substances emitted to water (l and/or tonnes) and disposed of to marine and freshwater environments (tonnes)	Health indicator related to marine and freshwater pollution

CONCLUSIONS, RECOMMENDATIONS AND NEXT STEPS

The NCIF presented here is a modest step towards identification and organization of a very large number of relevant indicators, into a coherent structure that is conducive to holistic assessment of natural capital and its interrelationships with development outcomes. Our recommended next steps for development and use of the NCIF are as follows:

- **Identify, develop and organize natural capital sub-indicators:** Our review highlights several potential coverage gaps in current range of natural capital indicators, which would need to be addressed to maximize the coverage and practical utility of the framework. Further work is needed to develop indicators to cover all significant ecosystems and other natural resources *(47)*. For example, there is a need for collaboration to identify, develop and organize specific indicators for: biodiversity as an indicator of asset condition; regulation and maintenance services generally; and the extent, condition and associated flows for marine assets generally.
- **Identify practical use cases for the framework and indicators:** There is a need to identify specific governance contexts in which natural capital indicators can enhance sustainability outcomes of decision-making, and develop practical and accessible guidance documentation supporting use of natural capital indicators that is specifically tailored to these contexts. There are use cases for natural capital indicators at multiple levels of governance:
    - At the inter-governmental level, elements of the NCIF could be adapted as appropriate to embed a natural capital perspective within broader indicator frameworks of sustainable development and green growth, for example those maintained by the OECD *(48)*, World Bank *(49)* and other multilateral institutions.
    - At a national level, elements of the NCIF could be embedded as appropriate within national indicator frameworks for sustainable development, progress reporting for the SDGs and other international commitments, and within economic performance assessment generally as a contextualizing complement to GDP.
- **Agree on top-level standards of natural capital:** A set of standards should be used by all countries to allow consistency and comparability among countries and an overall understanding of the state of natural capital. This should be flexible enough to be adapted to country-specific contexts (e.g. significant flows, values and ecosystem types).
- **Develop understanding of relationships between indicators across the framework:** The relationship between indicators across the multiple components of the framework could be used to infer information about the state of stocks and flows. For example, if human input indicators increase while benefit indicators remain constant, this may signal that the stock is degraded and requires increasing human effort to extract the same amount of flows and benefits. This information would be useful to inform decisions and monitor the impacts of policies.

On 16 July 2019, a workshop was held at the UN Headquarters in Geneva to discuss this report with the GGKP Natural Capital Working Group. Inspired by the discussions at this workshop, a number of additional next steps for development and use of the NCIF are recommended:

- **Develop guiding principles for using the framework:** A set of guiding principles should be developed to accompany the NCIF to support potential users in its application. This could include how to select the most appropriate indicators for the framework for specific contexts, how to apply the NCIF for different user types (e.g. public vs private use cases) and how to use the NCIF to incorporate natural capital into existing indicator frameworks. These principles could be developed during the testing of the potential applications and use cases of the NCIF.
- **Develop understanding of how trade-offs of different ecosystem services are captured by the NCIF:** There are likely to be trade-offs between different ecosystem services, and it should be understood whether and how this is captured by the NCIF. For example, timber extraction from a forest ecosystem will increase the biotic provisioning flow of timber resources while reducing multiple flows from forest ecosystems, including regulation and maintenance and cultural flows.

- **Define criteria for selecting indicators:** Criteria should be defined for selecting indicators for the NCIF. This will serve two purposes: provide more robustness to the choice of indicators in the NCIF, and guide users in the selection of alternative indicators if those provided in the NCIF are not appropriate for their context, for example if data availability restricts the indicators that can be produced in a country. Potential criteria could include data availability, thresholds, critical values and uncertainty ranges.
- **Select alternative social indicators for human inputs and clarification of overlap with social benefit indicators:** The social indicators of human inputs are currently limited to indicators of employment. However, there are other social characteristics of human inputs that are relevant to this component such as health, community and gender empowerment that should be considered for the NCIF. Such indicators are also relevant to the social benefits of natural capital, and it should be clarified how the overlap between the social indicators in the human inputs and benefits components should be dealt with.
- **Develop value indicators for ecosystem assets:** The present value of ecosystem assets can differ greatly from the present value of the SNA benefits derived from these assets. For example, in the UK National Accounts the value of standing trees in a forest ecosystem is an order of magnitude greater than the value of felled timber (this is implicit in the UK's most recent ecosystem services accounts *(50)*). Therefore, notwithstanding the difficulties, it is important to derive indicators of ecosystem asset values, and express them in net present value terms, as indicated in the NCIF. However, consideration of other ways of expressing ecosystem assets value is warranted.
- **Develop a governance component of the framework:** Indicators of governance of natural capital should be added to the NCIF. Governance is relevant to all components of the NCIF. Therefore its incorporation into the NCIF needs careful consideration.
- **Develop benchmarks for natural capital utilization, where appropriate and possible:** This could give insights into whether natural capital is being used efficiently in different contexts.
- **Add the ecosystem asset typology that is adopted by the SEEA EEA in 2020:** Once a typology of ecosystem assets is adopted by the SEEA EEA, work will be needed to populate the NCIF with appropriate ecosystem-specific indicators that align with this typology.
- **Develop link to climate change adaptation and resilience:** Due to the importance of this issue it would be useful to strengthen the link of the NCIF to climate adaptation and resilience. This could be done by selecting test cases that link to this issue.
- **Consider sub-national and private sector use cases:** The NCIF has been developed for public sector use at the national scale. However, it may be suitable for adaptation and use at the sub-national scale, and by the private sector such as for corporate and financial reporting. These use cases should be explored and tested.
- **Improve usability for policymakers:** Methods of making the NCIF more user-friendly for policymakers should be explored. This could include using graphic design to make the NCIF more visually appealing, and developing methods to support policymakers in choosing a smaller set of indicators from the NCIF for their context.
- **Clarify a number of specific indicators:** A number of specific recommendations were made for individual indicators, which should be clarified. This includes:
  - To have a clear definition of mineral reserves and with which intention the term should be used
  - To carefully look into if there is any case of double counting when capturing both the value of the land and the flows of benefits from the land
  - To consider whether the SDG 15.3 indicator on land degradation neutrality (proportion of land that is degraded over total land area) could be a good indicator for NCIF and included in the table
  - The proportion of green areas (differentiated by ecosystems) in urban areas could be also a good indicator
  - To consider using proxy indicators in those cases where it is difficult to measure quality as condition of the asset

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APPENDIX 1

A FOUR-CAPITAL MODEL OF WEALTH CREATION

Figure A1 illustrates a four-capital model of wealth creation, which was first put forward in Ekins 1992 (pp.147-151) and elaborated further in Ekins 2000 (pp. 51ff.) (A1), from which the following description is largely taken, and which includes further references to literature that helped with the model's derivation. The same model seems to have commended itself to Serageldin & Steer (1994, p.30) (A2) of the World Bank, who write of the "need to recognize at least four categories of capital", defined as in Figure 1A.

Figure A1 portrays four kinds of capital stock: ecological (or natural) capital, human capital, social and organizational capital, and manufactured capital. Each of these stocks produces a flow of "services" from the environment (E), from human capital (L), from social/organizational capital (S), and from physical capital (K), services which serve as inputs into the productive process, along with "intermediate inputs" (M), which are previous outputs from the economy which are used as inputs in a subsequent process. Other types of capital have been put forward, principally among them financial capital. However, financial capital, and the financial system through which it acts, may better be seen as a type of social capital, a conventional way of allocating and representing the power to mobilise the other four kinds of capital which have the real inherent power to deliver benefits.

The greyed boxes in Figure A1 indicate the stocks and flows related to natural capital, and include the categories that comprise the natural capital indicator framework described in more detail in the main paper.

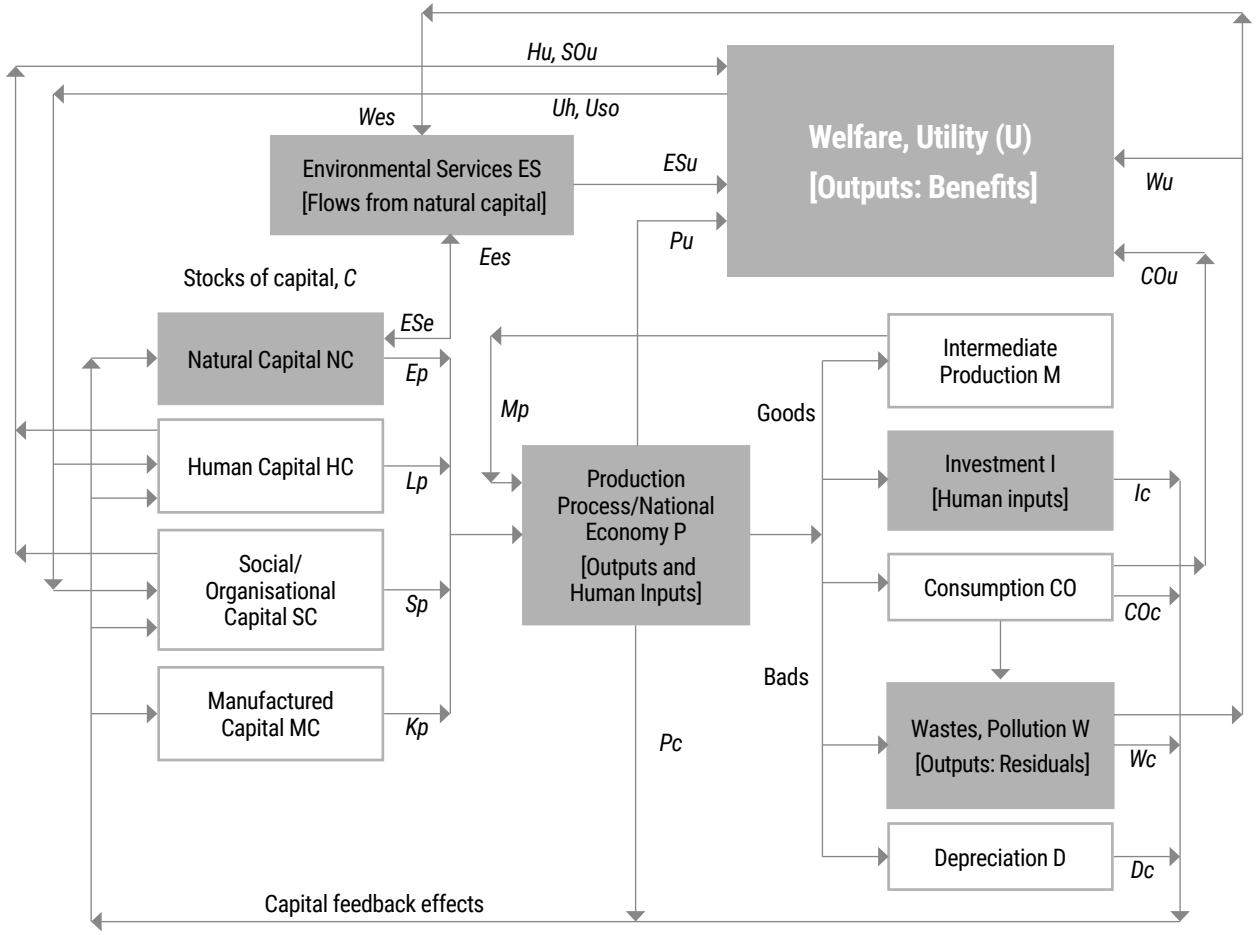

Figure A1. Four-capital model of wealth creation through a process of production.

Grey boxes highlight the components that are reflected in the natural capital indicator framework developed in this paper (assets, flows from natural capital, human inputs and outputs). Source: Ekins (1992) *(51)*.

Note: In the flow descriptors, the upper case letters denote the source of the flow; lower case letters denote the destination. Those relating to the various capital stocks have the C omitted for simplicity.

Manufactured capital comprises material goods—tools, machines, buildings, infrastructure—which contribute to the production process but do not become embodied in the output and, usually, are "consumed" in a period of time longer than a year. Intermediate goods, in contrast, either are embodied in produced goods (e.g. metals, plastics, components) or are immediately consumed in the production process (e.g. fuels). Human capital comprises all individuals' capacities for work, while social and organizational capital comprises the networks and organizations through which the contributions of individuals are mobilized and coordinated, and the shared norms, values and understandings which underpin their operation.

Ecological capital is a complex category which performs three distinct types of environmental function, two of which are directly relevant to the production process. The first is the provision of resources for production (E), the raw materials that become food, fuels, metals, timber, etc. The second is the absorption of wastes (W) from production, both from the production process and from the disposal of consumption goods. Where these wastes add to or improve the stock of ecological capital (e.g. through recycling or fertilisation of soil by livestock), they can be regarded as investment in such capital. More frequently, where they destroy, pollute or erode, with consequent negative impacts on the ecological, human or manufactured capital stocks, they can be regarded as agents of negative investment, depreciation or capital consumption. Either way, the wastes contribute to the capital feedback effects identified in Figure A1 (Wc).

The third type of environmental function does not contribute directly to production, but in many ways it is the most important type because it provides the basic context and conditions within which production is possible at all. It comprises basic "environmental services" (ES), including "survival services" such as those producing climate and ecosystem stability, shielding of ultraviolet radiation by the ozone layer, and "amenity services" such as the beauty of wilderness and other natural areas. These services are produced directly by ecological capital independently of human activity, but human activity can certainly have an (often negative) effect on the responsible capital and therefore on the services produced by it, through the capital feedback effects discussed earlier.

All kinds of capital can only be identified as such from the flows of benefits to which they give rise. Where these benefits can be given a money value, then the value of the capital stock from which they derive is simply the net present value of the benefit flow over time. The benefits are no less real if they cannot be so valued, but obviously in this case the capital stock that gives rise to them will need to be described, and perhaps quantified, in a different way. It is likely that in this evaluation there will be many examples of benefits, and therefore of capital stocks (especially social and natural), which it is difficult or impossible to give a money value to. The evaluation will have to take special care that these benefits and associated capital stocks are given due weight despite these difficulties. The flow of benefits from the capital stock implies a production process, in which the capitals may be combined.

The outputs of the production process can, in the first instance, be categorized as "goods" and "bads". The goods are the desired outputs of the process, as well as any positive externalities (incidental effects) that may be associated with it. These goods can be divided in turn into consumption, investment and intermediate goods and services. The bads are the negative effects of the production process, including capital depreciation and polluting wastes and other negative externalities, which contribute to environmental destruction, negative effects on human health, etc. Insofar as they have an effect on the capital stocks, the bads can be regarded as negative investment.

The necessity for a matter/energy balance on either side of the production process means that all matter and energy that feature as inputs must also emerge as outputs, either embodied in the goods or among the bads, which is one of the fundamental principles of physical input-output accounting in the framework of the national accounts. On disposal of the goods, all these former inputs are returned to the environment, to the stock of ecological capital, where they may have a positive, negative or neutral effect. The essential point is that, for matter, Figure A1 represents a closed system; for energy, inputs can be received from the sun, and heat can be radiated from the earth into space.

Some of the feedback processes in Figure A1 are as follows:

- Investment represents an addition to the capital stock (Ic), while depreciation of capital goods (Dc) or consumer durables (COc) reduces it.
- Wastes and pollution from the production process and consumption affect utility directly (Wu, e.g. litter, noise) and through their mainly negative feedback into the stocks of environmental, human and manufactured capital. These feedbacks, Wc, can reduce the productivity of environmental resources (e.g. through pollution) and affect the ecological capital that produces environmental services (e.g. by engendering climate change or damaging the ozone layer); they can damage human capital by engendering ill health; and they can corrode buildings (manufactured capital). They can also affect environmental services directly (Wes, e.g. by reducing the beauty of natural areas).
- Labour is the service delivered by an expanded concept of human capital, which includes such aspects of labour-power as knowledge, skills, health and motivation. Specifying human capital thus allows the model to recognise the direct relationships between human capital and welfare: a happy worker will be more productive (Uh); and a healthy worker will be happier as well as more productive (Hu).

- The concept of social/organizational capital reflects the considerable part played by institutions and social relations in wealth creation. Whereas human capital is embodied in individuals, social/organizational capital derives from their ways of interacting. As with human capital, social/organizational capital has a direct relationship with welfare. Social structures (e.g. the family) are major determinants of welfare (SOu), while the welfare of individuals will affect the performance of social structures (Uso).
- It may be seen from Figure A1 that utility is perceived as being generated by many other aspects of life apart from consumption. Broadly these can be classified according to the four modes of experience:

Being: affected by the quality of the environment (ESu), the nature and level of wastes (Wu), and the quality of human capital itself (Hu)

Having: derived from consumption (COu)

Doing: derived from the work process (Pu)

Interacting: derived from social and organizational structures as well as from the work process (SOu)

- There is a joint relationship between the stock of ecological capital (EC) and the environmental services (ES) deriving from it. In a stable ecosystem, EC and ES will tend to be symbiotically balanced.
- There is an important feedback from the work process to the human and social organisational capital stocks (Pc), reflected in the identification of such effects as "learning by doing" and in the perception that some work can "deskill" workers.

APPENDIX REFERENCES

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APPENDIX 2

Table A1. Alternative commodity and ecosystem asset indicators.

Ecosystem asset indicators are organized into illustrative generic terrestrial, freshwater and marine ecosystem groups (8.1-8.3) pending the development of a typology of ecosystem assets through the SEEA EEA Revision Process, except those indicators that are relevant to specific types of ecosystems which are organized using the USGS/Esri ecosystem type typology (terrestrial domain only) *(29)*. Quantity, quality and value indicators are indicated using the acronyms QN, QL and V, respectively.

Asset type	Indicators from other indicator initiatives
Headline indicator	**Natural Capital Asset Index** *(52, 53)*
Commodity assets	
1. Mineral and energy resources	
1.1. Oil resources	
1.2. Natural gas resources	
1.3. Coal and peat resources	
1.4. Non-metallic mineral resources (excluding coal and peat resources)	
1.5. Metallic mineral resources	
2. Land	
3. Soil resources	QL: Soil organic matter content, Soil carbon *(3)*; N, Corg in the soil, Loss of soil particles by wind or water *(54)*; Soil erosion risk or erosion protection, Soil organic matter content, pH of topsoil, Soil biodiversity (DNA-based richness and abundance), Soil pH (pH), Soil organic carbon (SOC) (% or g/kg), Soil moisture (water stress) (index), Bulk density (kg/m3), Soil erodibility (K-factor) (tonne ha h/MJ mm) *(55)*
4. Timber resources	QL: Area of forest under sustainable management: total FSC and PEFC forest management certification *(56)*
4.1. Cultivated timber resources	
4.2. Natural timber resources	
5. Aquatic resources	QL: Marine Trophic Index, Proportion of fish stocks within biologically sustainable levels *(56)*; Fisheries Stock Performance *(57)*
5.1. Cultivated aquatic resources	
5.2. Natural aquatic resources	QN: Trends in fisheries certified by the Marine Stewardship Council *(58)*; Trends in population of non-target species affected by fisheries *(59)* QL: Proportion of fish stocks within biologically sustainable levels *(60)*; Mean length of fish, Proportion of fish stocks within biologically sustainable levels *(58)*; Marine Trophic Index *(56)*
6. Other biological resources	QN: Land under cereal production (ha) *(58)*; Livestock *(55)* QL: Proportion of local breeds classified as being at risk, not-at-risk or at unknown level of risk of extinction *(56)*; Agrobiodiversity index *(61)*
7. Water resources	QN: Internal renewable freshwater resources. Per capita cubic meters, Internal renewable freshwater resources Flows billion cu. M *(62)* QL: SDG 6.3.2 Proportion of bodies of water with good ambient water quality *(60)*; Freshwater quality *(63)*

Asset type	Indicators from other indicator initiatives
Headline indicator	**Natural Capital Asset Index** *(52, 53)*
7.1. Surface water	QN: Permanent surface water, % total surface, Seasonal surface water, % total surface, Conversion of permanent water to not-water surface, % permanent water, since 1984, Conversion of permanent to seasonal water surface, % permanent water, since 1984, Conversion of not-water to permanent water surface, % permanent water, since 1984, Conversion of seasonal to permanent water surface, % permanent water, since 1984 *(10)* QL: Surface water body status *(64)*
7.2. Groundwater	
7.3. Soil water	
Ecosystem assets	
8. Ecosystems & conditions	QL: Global Ecosystem Restoration Index *(58)*; Human Appropriation of Net Primary Production (HANPP), Biodiversity Habitat Index *(55)*; Living Planet Index *(43)*; Naturalness (index or typology), Invasive alien species (number or richness) (number of species/area unit), Phylogenetic diversity (index), Population sizes of species of interest, Amount of biomass, Population abundance (MSFD D1C2) (number of individuals/species or tonne/species), Abundance and spatial distribution of established non-indigenous species, particularly of invasive species, contributing significantly to adverse effects on particular species groups or broad habitat types (MSFD-D2C2) (number of individuals or tonne or km2 per species), Proportion of the species group or spatial extent of the broad habitat type which is adversely altered due to non-indigenous species, particularly invasive non-indigenous species (MSFD-D2C3) (ratio or km2), Presence of invasive alien species reported under the EU Regulation (IAS 1143/2014) *(55)*
8.1. Ecosystem type (Terrestrial)	QN: Distribution of wild berries *(55)*; Natural and semi-natural vegetated land, % total, Loss of natural and semi-natural vegetated land, % since 1992 and 2004, Gain of natural and semi-natural vegetated land, % since 1992 and 2004 *(10)*; Losses of land covered by (semi-)natural vegetation *(65)*; AT 5.5.2 - Natural habitat extent (land area minus urban and agriculture) *(59)* QL: Leaf-related indicators, Pigment content (chlorophyll, carotene xanthophyll) (µg/g), Content of: nitrogen, phosphorous, carbon, lignin, cellulose, phenole, plant water content, wax, starch, sugar (%), Species diversity, richness (number and abundance of species, including vascular plants, vertebrates, etc.) (number of species, indexes), Rove and ground beetles (species richness), Bryophyte, moss, liverwort, lichen and fungal species richness, Photosynthesis (e.g. indexes: NDVI (Normalized Difference Vegetation Index), VCI Copernicus (Vegetation Condition Index), fPAR (Fraction of Photosynthetically active radiation), LAI (Leaf Area Index)) (CI), Chlorophyll fluorescence (remote sensing proxies), Carbon sequestration (Dry matter productivity Copernicus) (tonne/ha/year), Plant productivity (NPP) (tonne/ha/year), Evapotranspiration (l/ha/day), Leaf respiration (net ecosystem–atmosphere CO2 exchange), Leaf phenology type, leaf age, leaf development (measures according to annual cycles), Plant and canopy phenology (measures according to annual cycles), Carbon dioxide exchange and carbon balance (net ecosystem–atmosphere CO2 exchange), Greening response (remote sensing proxies), Available water capacity (index), Nutrient availability (nitrogen and phosphorus) (mg/kg), Deadwood (m3/ha), Plant functional types (typology), Landscape fragmentation index (index), Density of semi-natural elements (%/ha), Connectivity of semi-natural elements (index) *(55, 66)*

Asset type	Indicators from other indicator initiatives
Headline indicator	**Natural Capital Asset Index** *(52, 53)*
8.1.1. Forestlands	QN: Forest area as % of total land area, Trends in forest extent *(58)*; SDG 15.1.1 Forest area as a proportion of total land area *(60)*; Forestland (ha) *(67)*; Forest area % of land area *(62)*; Area occupied by riparian forests *(55)* QL: Forests under sustainable management certification, % total forest area *(10)*; Percentage of forest designated as "protective forests" (soil, water, other functions and infrastructure and managed resources) (%) *(66)*; Forest types (typology), Forest age structure (% of forest in age categories), Seral diversity (typology), Defoliation (% of trees), Discolouration (% of trees), Tree height (m), Tree cover density (%), Tree crown size (diameter, m), Forest fragmentation and connectivity (index), Biomass volume (growing stock) (m3/ha), Carbon stock (tonne/ha), Forest area (km2), Forest structural heterogeneity (index from remote sensing), Forest structural homogeneity (index from remote sensing), Canopy volume (from remote sensing) (m3), Naturalness (index or typology), Leaf-related indicators, Pigment content (chlorophyll, carotene xanthophyll) (µg/g), Forest tree species (number of species or species richness), tree sp. composition (index), Genetic variability (index; % of forest managed for the conservation and utilization of forest tree genetic resources), Threatened forest species (red list index), Threatened forests related habitats (Red List index) (%, number, area), Abundance and distribution of common forest birds, Conservation status and trends of species of Community interest associated to forest (%), EU Population status and trends of bird species of Community interest associated to forest (%) *(55, 66)*
8.1.2. Shrublands	QL: Threatened heathlands (or) sparsely vegetated land related habitats (%, number, area), Conservation status & trends of habitats of Community interest associated to heathlands (or) sparsely vegetated land (%), Conservation status & trends of species of Community interest associated to heathlands (or) sparsely vegetated land (%), EU Population status & trends of bird species associated to heathlands (or) sparsely vegetated land (%) *(55)*
8.1.3. Grasslands	QL: Grassland habitat fragmentation (meshes/1000 km2), Grassland Butterfly Indicator, Mammals, amphibians, reptiles impacted by changes in agriculture (Red List index), Conservation status and trends of habitats of Community interest associated to grassland (%), EU Population status and trends of bird species associated to cropland and grassland (%), Conservation status and trends of species of Community interest associated to cropland and grassland (%) *(55, 66)*
8.1.4. Woodlands and Savannas	QL: Percentage of forest designated as "protective forests" (soil, water, other functions and infrastructure and managed resources) (%); Forest types (typology), Forest age structure (% of forest in age categories), Seral diversity (typology), Defoliation (% of trees), Discolouration (% of trees), Tree height (m), Tree cover density (%), Tree crown size (diameter, m), Forest fragmentation and connectivity (index), Biomass volume (growing stock) (m3/ha), Carbon stock (tonne/ha), Forest area (km2), Forest structural heterogeneity (index from remote sensing), Forest structural homogeneity (index from remote sensing), Canopy volume (from remote sensing) (m3), Forest tree species (number of species or species richness), tree sp. composition (index), Genetic variability (index; % of forest managed for the conservation and utilization of forest tree genetic resources), Threatened forest species (red list index), Threatened forests related habitats (Red List index) (%, number, area), Abundance and distribution of common forest birds, Conservation status and trends of species of Community interest associated to forest (%), EU Population status and trends of bird species of Community interest associated to forest (%) *(55, 66)*
8.1.5. Barren Lands	QN: Bare land % total *(10)* QL: Threatened heathlands (or) sparsely vegetated land related habitats (%, number, area), Conservation status & trends of habitats of Community interest associated to heathlands (or) sparsely vegetated land (%), EU Population status & trends of bird species associated to heathlands (or) sparsely vegetated land (%) *(55, 66)*

Asset type	Indicators from other indicator initiatives
Headline indicator	**Natural Capital Asset Index** *(52, 53)*
8.1.6. Croplands	QN: Cropland % total, Conversion from natural and semi-natural land to cropland, % since 1992, Conversion from cropland to artificial surfaces, % since 1992 *(10)*; Permanent cropland % of land area, Arable land % of land area, Agricultural land % of land area, Land under cereal production hectares thousands *(62)* QL: Areas of agricultural land under organic production; Areas of agricultural land under conservation agriculture; Proportion of agricultural area under productive and sustainable agriculture *(59)*; Crop diversity/ 10 km×10 km (number), Crop rotation (functional crop groups) (number), Share of fallow land in UAA (%), Share of High Nature Value farmland in agricultural area (%), Share of organic farming in UAA (%), Livestock density (LU/ha), Farmland Bird Indicator, Mammals, amphibians, reptiles impacted by changes in agriculture (Red List index), Wild pollinators (where available) (species richness), Percentage of agroecosystems covered by Natura 2000 (%), EU Population status and trends of bird species associated to cropland and grassland (%), Conservation status and trends of species of Community interest associated to cropland and grassland (%) *(55, 66)*; Agrobiodiversity index *(61)*
8.1.7. Built Environment	QN: Artificial land % total, Built up area % total, Conversion from natural and semi-natural land to artificial surfaces, % since 1992, Conversion from cropland to artificial surfaces, % since 1992, New built up area since 1990 and 2000 *(10)*; Percentage of urban green space (%) *(66)* QL: Connectivity of urban green spaces (%), Fragmentation of urban green space (Mesh density per pixel) *(55, 66)*
8.2. Ecosystem type (Freshwater and Wetlands)	QN: SDG 6.6.1 Change in the extent of water-related ecosystems over time *(60)*; Water % total *(10)*; Floodplains areas *(55)*; Change in the extent of water-related ecosystems over time *(59)* QL: SDG 6.3.2 Proportion of bodies of water with good ambient water quality *(60)*; Water Quality Index for Biodiversity *(56)*; Photosynthesis (e.g. indexes: NDVI (Normalized Difference Vegetation Index), VCI Copernicus (Vegetation Condition Index), fPAR (Fraction of Photosynthetically active radiation), LAI (Leaf Area Index)) (CI), Chlorophyll fluorescence (remote sensing proxies), Available water capacity (index), Freshwater chemical status, Bathing water quality (quality levels), Ecological Status of water bodies, Flow alteration (%) (ex. days the environmental flow is not respected in a year), Water Exploitation Index (%), Land cover in the drained area or floodplain (%) (ex. natural areas in floodplains, Density of infrastructures in floodplains, Artificial land cover or soil sealing in floodplains, Agricultural land cover in floodplains, Ecosystem coverage), Density of dams in the drained area (number/km2)**, Ecological Status (CI), Biological quality elements (BQEs) collected to assess ecological status (ex. composition and abundance of aquatic flora, benthic invertebrate fauna, fish fauna, phytoplankton), Presence of alien species reported under the EU Regulation (1143/2014) (number), Threatened freshwater related habitats (%, number, area) *(55, 66)*
8.2.1. Rivers and Streams	QN: Area occupied by riparian forests *(55)* QL: Conservation status and trends of habitats of Community interest associated to rivers & lakes (%), Conservation status and trends of species of Community interest associated to rivers & lakes (%), EU population status and trends of bird species associated to rivers & lakes (%) (CI) *(55, 66)*
8.2.2. Lakes and Ponds	QL: Conservation status and trends of habitats of Community interest associated to rivers & lakes (%), Conservation status and trends of species of Community interest associated to rivers & lakes (%), EU population status and trends of bird species associated to rivers & lakes (%) (CI) *(55, 66)*

Asset type	Indicators from other indicator initiatives
Headline indicator	**Natural Capital Asset Index** *(52, 53)*
8.2.3. Freshwater Wetlands	QN: AT 5.5.3 - Wetland extent *(59)*; Wetland extent trend index *(58)* QL: Trend in wetland condition *(68)*; Wetland connectivity indicator (< 10 km from other wetland / > 10 km from other wetland), Threatened wetlands related habitats (%, number, area), Living Planet Index for Mediterranean wetlands (CI), Number & abundance of wetland bird species (number/ha), Status of globally-threatened wetland-dependent birds/amphibians *(55, 66)*
8.2.4. Estuaries	
8.3. Ecosystem type (Marine)	QN: Change in the extent of water-related ecosystems over time *(59)*; Live Coral Cover *(56)*; SDG 6.6.1 Change in the extent of water-related ecosystems over time *(60)* QL: AT 14.3.4 - Ocean Health Index *(59)*; Water Quality Index for Biodiversity, Live Coral Cover *(56)*; Oxyrisk, Oxygen concentration, Marine species distribution, Nutrient load to coast, HM and POP loading, Marine carbon stock, Marine pH, Blue carbon, Marine primary productivity, Dissolved oxygen at the bottom of the water column (MSFD-D5C5) (mg/l), Bathing water quality (quality levels), Contaminants concentration in seafood (MSFD-D9C1) (mg/kg), Composition, amount and spatial distribution of litter (MSFD-D10C1) (number of items/m or /km2), Composition, amount and spatial distribution of micro-litter (MSFD-D10C2) (g/m2 or g/kg of sediment), Spatial distribution, temporal extent, and levels of anthropogenic impulsive sound sources (MSFD-D11C1) (km2), Spatial distribution, temporal extent and levels of anthropogenic continuous low-frequency sound (MSFD-D11C2) (km2), Ecological status (WFD), Spatial extent and distribution of physical loss/disturbance to seabed (MSFD-D6C1 and D6C2) (km2), Spatial extent of adversely affected benthic habitat (MSFD-D6C3) (km2), Extent of loss of benthic habitat type (MSFD-D6C4) (km2), Extent of adverse effect on benthic habitat type (MSFD-D6C5) (km2), Spawning Stock Biomass (MSFD-D3C2) (tonne), Age and size distribution of commercially-exploited species (MSFD-D3C3) (% or number or cm), Biological quality elements (BQEs) collected to assess ecological status (ex. composition and abundance of aquatic flora, benthic invertebrate fauna, fish fauna, phytoplankton), Population status and trends of bird species of Community interest associated to transitional and coastal waters (%) (CI), Conservation status and trends of habitats of Community interest associated to transitional and coastal waters (%) (CI), Conservation status and trends of species of Community interest associated to transitional and coastal waters (%) (CI) *(55, 66)*

Table A2. Alternative commodity and ecosystem flow indicators.

Ecosystem asset indicators are organized into illustrative generic terrestrial, freshwater and marine ecosystem groups (8.1-8.3) pending the development of a typology of ecosystem assets through the SEEA EEA Revision Process, except those indicators that are relevant to specific types of ecosystems, which are organized using the USGS/Esri ecosystem type typology (terrestrial domain only) *(29)*. Types of ecosystem services flows are indicated by P (Provisioning), R&M (Regulation & Maintenance), C (Cultural), B (Biotic) and A (Abiotic) following the Common International Classification of Ecosystem Services *(25)*.

Asset type	Related indicators from other indicator initiatives
Commodity assets	
1. Mineral and energy resources	
1.1. Oil resources	
1.2. Natural gas resources	
1.3. Coal and peat resources	
1.4. Non-metallic mineral resources (excluding coal and peat resources)	
1.5. Metallic mineral resources	
2. Land	
3. Soil resources	R&M (B): C pools [m, ml-2t-1], conductivity [Cl-1], crop growth [mt-1], decomposition rate [mt-1], detritivore feeding rate [mt-1], fine roots [nt-1], mineralization rate [m, mt-1], N [m, ml-2t-1, mt-1], NO3- [ml-2], P [m], sediment [l3], sedimentation cone area [l2], soil organic carbon (SOC) [m], topsoil turned over by earthworms [ml-2t-1], useful species abundance [m], water holding capacity [l3], yield loss [m] *(46)*
4. Timber resources	P (B): Total wood removals *(58)*, wood growth [ml-2t-1], wood stock [ml-2], wood yield [lt-1, ml-2t-1] *(46)*
4.1. Cultivated timber resources	
4.2. Natural timber resources	
5. Aquatic resources	P (B): Yield and landings *(55)*; Inland fisheries production *(58)*; Fish yield [m, mt-1], plant yield *(46)*
5.1. Cultivated aquatic resources	P (B): Freshwater aquaculture production *(55)*
5.2. Natural aquatic resources	P (B): Estimated fisheries catch and fishing effort *(58)*
6. Other biological resources	P (B): Crop production index, Livestock production index, Cereal yield *(62)*; Area and yields of food and feed crops, Livestock *(55)*
7. Water resources	P (A): Water Footprint *(58)*; SDG 6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources *(60)*; Total freshwater abstraction per capita *(10)*; Annual freshwater withdrawals billion cu. M, Annual freshwater withdrawals % of internal resources *(62)* R&M (A): Landscape index [0], reduced flood risk area [l2, l2p-1], settlement area [l2], storage and permeability capacity [0], water [lt-1] *(46)*
7.1. Surface water	
7.2. Groundwater	
7.3. Soil water	

Asset type	Related indicators from other indicator initiatives
Ecosystem assets	
8. Ecosystems & conditions	P (B): Threatened species of mammals, birds, fish and higher plants *(62)*; AT Red List Index (impacts of fisheries) *(59)* R&M (B): C pools [m, ml-2t-1], detritivore feeding rate [mt-1], soil organic carbon (SOC) [m], useful species abundance [m] *(46)* R&M (A): Conductivity [Cl-1], mineralization rate [m, mt-1], N [m, ml-2t-1, mt-1], NO3- [ml-2], P [m], sediment [l3], sedimentation cone area [l2], water holding capacity [l3] *(46)*
8.1. Ecosystem type (Terrestrial)	R&M (B): Decomposition rate [mt-1], detritivore feeding rate [mt-1], fine roots [nt-1], soil organic carbon (SOC) [m], topsoil turned over by earthworms [ml-2t-1] *(46)*
8.1.1. Forestlands	P (B): Total wood removals *(58)*; Wood growth [ml-2t-1], wood stock [ml-2], wood yield [lt-1, ml-2t-1] *(46)* R&M (B): Nitrogen and Sulphur removal (forests), Carbon storage and sequestration by forests *(55)* P (A): Total supply of water per forest area (modelling) *(55)*
8.1.2. Shrublands	
8.1.3. Grasslands	
8.1.4. Woodlands and Savannas	P (B): Total wood removals *(58)*; Wood growth [ml-2t-1], wood stock [ml-2], wood yield [lt-1, ml-2t-1] *(46)*
8.1.5. Barren Lands	
8.1.6. Croplands	P (B): Crop production index, Livestock production index, Cereal yield *(62)*; Area and yields of food and feed crops, Livestock *(55)*; Crop & by-product [ml-2t-1], crop yield [m, ml-2], livestock units, crop growth [mt-1] *(46)* R&M (B): Red List Index (pollinating species) *(56)*; Pollination potential *(55)*
8.1.7. Built Environment	
8.2. Ecosystem type (Freshwater and Wetlands)	P (B): Yield and landings *(55)*; Inland fisheries production *(58)*; Fish yield [m, mt-1], plant yield *(46)* P (A): Water Footprint *(58)*; SDG 6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources *(60)*; Total freshwater abstraction per capita *(10)*; Annual freshwater withdrawals billion cu. M, Annual freshwater withdrawals % of internal resources *(62)* R&M (B): C pools [m, ml-2t-1], detritivore feeding rate [mt-1] *(46)* R&M (A): Landscape index [0], reduced flood risk area [l2, l2p-1], settlement area [l2], storage and permeability capacity [0], water [lt-1], conductivity [Cl-1], mineralization rate [m, mt-1], N [m, ml-2t-1, mt-1], NO3- [ml-2], P [m], sediment [l3], sedimentation cone area [l2], water holding capacity [l3] *(46)*
8.2.1. Rivers and Streams	
8.2.2. Lakes and Ponds	
8.2.3. Freshwater Wetlands	
8.2.4. Estuaries	
8.3. Ecosystem type (Marine)	P (B): Yield and landings *(58)*; Fish yield [m, mt-1], plant yield *(46)* R&M (B): Marine carbon sequestration *(55)*; C pools [m, ml-2t-1], detritivore feeding rate [mt-1] *(46)* R&M (A): Reduced flood risk area [l2, l2p-1], storage and permeability capacity [0], water [lt-1], mineralization rate [m, mt-1], N [m, ml-2t-1, mt-1], NO3- [ml-2], P [m], sediment [l3], sedimentation cone area [l2], water holding capacity [l3], conductivity [Cl-1] *(46)*

Table A3. Alternative human inputs indicators for commodity and ecosystem assets.

Ecosystem asset indicators are organized into illustrative generic terrestrial, freshwater and marine ecosystem groups (8.1-8.3) pending the development of a typology of ecosystem assets through the SEEA EEA Revision Process, except those indicators that are relevant to specific types of ecosystems which are organized using the USGS/Esri ecosystem type typology (terrestrial domain only) *(29)*.

Asset	Economic	Social
Commodity assets		
1. Mineral and energy resources		
1.1. Oil resources		
1.2. Natural gas resources		
1.3. Coal and peat resources		
1.4. Non-metallic mineral resources (excluding coal and peat resources)		
1.5. Metallic mineral resources		
2. Land		
3. Soil resources		
4. Timber resources		
4.1. Cultivated timber resources		
4.2. Natural timber resources		
5. Aquatic resources		
5.1. Cultivated aquatic resources		
5.2. Natural aquatic resources		
6. Other biological resources	Trends in pesticide use *(58)*	Agricultural employment % of total employment *(62)*; TEEB Number of jobs provided by a particular type of agricultural production; SDG 8.3.1 Proportion of informal employment in non-agriculture employment, by sex *(60)*
7. Water resources		SDG 6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources *(60)*
7.1. Surface water		
7.2. Groundwater		
7.3. Soil water		

Ecosystem assets		
8. Ecosystems & conditions	SDG 11.4.1 Total expenditure (public and private) per capita spent on the preservation, protection and conservation of all cultural and natural heritage, by type of heritage (cultural, natural, mixed and World Heritage Centre designation), level of government (national, regional and local/municipal), type of expenditure (operating expenditure/investment) and type of private funding (donations in kind, private non-profit sector and sponsorship) *(60)*	
8.1. Ecosystem type (Terrestrial)		
8.1.1. Forestlands		
8.1.2. Shrublands		
8.1.3. Grasslands		
8.1.4. Woodlands and Savannas		
8.1.5. Barren Lands		
8.1.6. Croplands	Trends in pesticide use *(58)*	
8.1.7. Built Environment		
8.2. Ecosystem type (Freshwater and Wetlands)		
8.2.1. Rivers and Streams		
8.2.2. Lakes and Ponds		
8.2.3. Freshwater Wetlands		
8.2.4. Estuaries		
8.3. Ecosystem type (Marine)		

Table A4. Alternative output indicators for benefits and residuals.

Types of ecosystem services flows are indicated by P (Provisioning), R&M (Regulation & Maintenance), C (Cultural), B (Biotic) and A (Abiotic) following the Common International Classification of Ecosystem Services *(25)*. Ecosystem asset indicators are organized into illustrative generic terrestrial, freshwater and marine ecosystem groups (8.1-8.3) pending the development of a typology of ecosystem assets through the SEEA EEA Revision Process, except those indicators that are relevant to specific types of ecosystems which are organized using the USGS/Esri ecosystem type typology (terrestrial domain only) *(29)*.

Asset/Residual	Related indicators from other indicator initiatives (Economic)	Related indicators from other indicator initiatives (Social)	Related indicators from other indicator initiatives (Environmental)
Benefits			
Commodity assets			
1. Mineral and energy resources	P (A): Mineral rents % of GDP *(62)*	P (A): Access to modern energy (%) *(67)*; Access to electricity % of population *(62)*; SDG 7.1.1 Proportion of population with access to electricity, SDG 4.a.1 Proportion of schools with access to (a) electricity; (b) the Internet for pedagogical purposes; (c) computers for pedagogical purposes; (d) adapted infrastructure and materials for students with disabilities; (e) basic drinking water; (f) single-sex basic sanitation facilities; and (g) basic handwashing facilities (as per the WASH indicator definitions) *(60)*	NA
1.1. Oil resources	P (A): Oil % of total energy use, per capita Oil rents % of GDP *(62)*		NA
1.2. Natural gas resources	P (A): Natural gas % of total energy use, per capita, Natural gas rents % of GDP *(62)*		NA
1.3. Coal and peat resources	P (A): Coal % of total energy use, per capita, Coal rents % of GDP *(62)*		NA
1.4. Non-metallic mineral resources (excluding coal and peat resources)	P (A): Mineral rents % of GDP *(62)*		NA
1.5. Metallic mineral resources	P (A): Mineral rents % of GDP *(62)*		NA
2. Land			NA
3. Soil resources			NA
4. Timber resources	P (B): Forest rents % of GDP *(62)*		NA
4.1. Cultivated timber resources			NA
4.2. Natural timber resources			NA
5. Aquatic resources			NA
5.1. Cultivated aquatic resources			NA
5.2. Natural aquatic resources			NA

Asset/Residual	Related indicators from other indicator initiatives (Economic)	Related indicators from other indicator initiatives (Social)	Related indicators from other indicator initiatives (Environmental)
6. Other biological resources		P (B): SDG 5.a.1 (a) Proportion of total agricultural population with ownership or secure rights over agricultural land, by sex; and (b) share of women among owners or rights-bearers of agricultural land, by type of tenure *(60)*	NA
7. Water resources		P (A): Percentage of population using safely managed drinking water services *(58)*; SDG 3.9.2 Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH) services), SDG 4.a.1 Proportion of schools with access to (a) electricity; (b) the Internet for pedagogical purposes; (c) computers for pedagogical purposes; (d) adapted infrastructure and materials for students with disabilities; (e) basic drinking water; (f) single-sex basic sanitation facilities; and (g) basic handwashing facilities (as per the WASH indicator definitions), SDG 6.1.1 Proportion of population using safely managed drinking water services, SDG 6.2.1 Proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water *(60)*; Access to water (%), Access to sanitation (%), Level of harmful chemicals in drinking water (g/litre) *(67)*; Access to improved water source. % of total population, People using at least basic drinking water services. % of urban/rural population *(62)*.	NA
7.1. Surface water			NA
7.2. Groundwater			NA
7.3. Soil water			NA

Asset/Residual	Related indicators from other indicator initiatives (Economic)	Related indicators from other indicator initiatives (Social)	Related indicators from other indicator initiatives (Environmental)
Ecosystem assets			
8. Ecosystems & conditions	P (B): Gross ecosystem product *(69)* R&M (B): Gross ecosystem product *(69)* C (B): Gross ecosystem product *(69)*; Visitor statistics *(55)* P (A): Gross ecosystem product *(69)* R&M (A): Gross ecosystem product *(69)*	R&M (B): Percentage of population using outdoor space for exercise/ health reasons (Department of Health, 2016, 70) C (B): Number of tourist visits to ecosystem-based attractions *(70)*	NA
8.1. Ecosystem type (Terrestrial)			NA
8.1.1. Forestlands	P (B): Forest rents % of GDP *(62)*		NA
8.1.2. Shrublands			NA
8.1.3. Grasslands			NA
8.1.4. Woodlands and Savannas	P (B): Forest rents % of GDP *(62)*		NA
8.1.5. Barren Lands			NA
8.1.6. Croplands		P (B): TEEB Agricultural income as a fraction of household income in poverty-affected areas; TEEB Food output distributed to food-insecure areas as a fraction of total farm output; TEEB Risks and uncertainties related to human health posed by different agricultural systems C (B): SDG 5.a.1 (a) Proportion of total agricultural population with ownership or secure rights over agricultural land, by sex; and (b) share of women among owners or rights-bearers of agricultural land, by type of tenure *(60)*	NA
8.1.7. Built Environment			NA

Asset/Residual	Related indicators from other indicator initiatives (Economic)	Related indicators from other indicator initiatives (Social)	Related indicators from other indicator initiatives (Environmental)
8.2. Ecosystem type (Freshwater and Wetlands)		P (A): Percentage of population using safely managed drinking water services *(58)*; SDG 3.9.2 Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH) services), SDG 4.a.1 Proportion of schools with access to (a) electricity; (b) the Internet for pedagogical purposes; (c) computers for pedagogical purposes; (d) adapted infrastructure and materials for students with disabilities; (e) basic drinking water; (f) single-sex basic sanitation facilities; and (g) basic handwashing facilities (as per the WASH indicator definitions), SDG 6.1.1 Proportion of population using safely managed drinking water services, SDG 6.2.1 Proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water *(60)*; Access to water (%), Access to sanitation (%), Level of harmful chemicals in drinking water (g/litre) *(67)*; Access to improved water source. % of total population, People using at least basic drinking water services. % of urban/rural population *(62)*	NA
8.2.1. Rivers and Streams			NA
8.2.2. Lakes and Ponds			NA
8.2.3. Freshwater Wetlands			NA
8.2.4. Estuaries			NA
8.3. Ecosystem type (Marine)			NA

Asset/Residual	Related indicators from other indicator initiatives (Economic)	Related indicators from other indicator initiatives (Social)	Related indicators from other indicator initiatives (Environmental)
Residuals			
Solid waste			Municipal waste generated, kg per capita, Municipal waste disposed to landfills, % treated waste, Municipal waste incinerated, % treated waste, Municipal waste recycled or composted, % treated waste *(10)*; Waste generation (ton/year) or landfill area (ha) *(67)*
Waste water		Number of households linked to sewage system, Percentage of sewage coverage in the country, No. wastewater treatment plants; Health index related to waste water *(68)*	SDG 6.3.1 Proportion of wastewater safely treated *(60)*
Emissions		Carbon dioxide emissions by sector *(62)*	Total greenhouse gas emissions thousand metric tons of carbon dioxide equivalent *(62)*; GHG emissions from land use *(65)*; Trends in nitrogen deposition, Trends in loss of reactive nitrogen to the environment *(56)*; Heavy metals and persistent organic pollutants deposition *(55)*

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