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The IPBES Conceptual Framework — connecting nature and people

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The first public product of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) is its Conceptual Framework. This conceptual and analytical tool, presented here in detail, will underpin all IPBES functions and provide structure and comparability to the syntheses that IPBES will produce at different spatial scales, on different themes, and in different regions. Salient innovative aspects of the IPBES Conceptual Framework are its transparent and participatory construction process and its explicit consideration of diverse scientific disciplines, stakeholders, and knowledge systems, including indigenous and local knowledge. Because the focus on co-construction of integrative knowledge is shared by an increasing number of initiatives worldwide, this framework should be useful beyond IPBES, for the wider research and

knowledge-policy communities working on the links between nature and people, such as natural, social and engineering scientists, policy-makers at different levels, and decision-makers in different sectors of society.

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Introduction[88]

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) was established in 2012 as an independent intergovernmental body open to all member countries of the United Nations, with the goal of 'strengthening the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development' (http://www.ipbes.net). Developed in the wake of other international assessments, specifically the Millennium Ecosystem Assessment and the Intergovernmental Panel on Climate Change (IPCC), IPBES was designed to proactively develop assessments matched to policy needs, and to support capacity building across scales and topics [1,2]. To achieve this objective, IPBES has four interconnected functions: to catalyse the generation of new knowledge; to produce assessments of existing knowledge; to support policy formulation and implementation; and to build capacities relevant to achieving its goal. The first public product of IPBES was a conceptual framework to underpin all these functions, to structure the syntheses that will inform policy, and to improve comparability across various assessments carried out at different spatial scales, on different themes, and in different regions.

Conceptual frameworks, in the context of IPBES, might be described as 'a concise summary in words or pictures of relationships between people and nature'. In other words, conceptual frameworks depict key social and ecological components, and the relationships between these components. They provide common terminology and structure for the variables that are the focus of a system analysis, and propose assumptions about key relationships in the system. Conceptual frameworks have the ability to provide a shared language and a common set of relationships and definitions to make complex systems as simple as they need to be for their intended purpose. Integrative conceptual frameworks are particularly useful tools in fields requiring interdisciplinary collaboration where they are used to make sense of complexity [3,4] by clarifying and focusing thinking about relationships, supporting communication across disciplines and knowledge systems and between knowledge and policy [5].

In this article, we present a detailed description of the Conceptual Framework approved by the IPBES Second Plenary, aimed not only for those involved in IPBES work but also as a general integrative framework of potential interest for members of the wider research and knowledge-policy communities focusing on the links between nature and people. The IPBES Conceptual Framework (hereafter CF) is a highly simplified model of the complex interactions between the natural world and human societies that are most relevant to IPBES's goal. It builds on the basis of previous influential conceptual frameworks [3,6] and most notably the Millennium Ecosystem Assessment [7,8].

The work of IPBES is innovative in two respects. First, it has been constructed in a transparent, inclusive and participatory manner, through multidisciplinary workshops and open review by a broad range of countries and stakeholders over more than two years (Box 1). Second, it explicitly embraces different scientific disciplines (natural, social, engineering sciences), as well as diverse stakeholders (the scientific community, governments, international organizations, and civil society at different levels), and their different knowledge systems (western science, indigenous, local and practitioners' knowledge).

Key features of the IPBES Conceptual Framework

The CF starts with consideration of the goal of the platform, '. . .conservation and sustainable use of biodiversity, long-term human well-being and sustainable development', and therefore the key elements (or components) are nature, the benefits that people derive from nature and a good quality of life. In a shift of focus with respect to most previous initiatives, the CF also highlights the central role that institutions, governance and decision-making play on the links among these elements. Most importantly, the CF explicitly includes multiple knowledge systems. The main elements, their interlinkages and the different knowledge systems are all represented in Figure 1.

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[88] Key terms used in this article are defined in the Glossary.

Box 1 The process of developing the IPBES Conceptual Framework

Discussions that led to the IPBES CF had their origins long before the formal establishment of IPBES, and built on the experiences in developing and using the Millennium Ecosystem Assessment conceptual framework and various other processes, including two informal international workshops in Tokyo (2011 and 2012). At the time of the official establishment of IPBES in Panama in April 2012, the IPBES Secretariat was requested to prepare a draft conceptual framework document, drawing on and informed by existing conceptual frameworks, and to make this available for online review through an open and transparent process. In support of his work, an informal expert workshop on a conceptual framework for IPBES was organized by UNESCO in Paris in October 2012, supported by IUCN and the Ministry of the Environment of Japan. The outcome of this workshop was made available online by the IPBES Secretariat from December 2012 to March 2013, and submitted as a background document to IPBES-1 (Bonn, December 2013). Feedback from this consultation and discussions at IPBES-1 were compiled by the IPBES Secretariat and taken as the basis for a formal International Expert Workshop on the Conceptual Framework for IPBES, (Cape Town, August 2013), hosted and supported by the Governments of South Africa, the United Kingdom, and Japan. The workshop was attended by 28 experts from multiple disciplines, representatives from relevant Multilateral Environment Agreement scientific subsidiary bodies, as well as from UNEP, FAO, UNDP and UNESCO, and members of the IPBES Bureau and Multidisciplinary Expert Panel (MEP). The outcome of this workshop was further considered by the MEP, who subsequently proposed a conceptual framework to the IPBES Plenary at its second meeting. The Conceptual Framework (CF) was adopted by IPBES-2 in Antalya in December 2013 [84]. See http://www.ipbes.net/ http://www.ipbes.net/ for full documentation related to this process.

The different knowledge systems are indicated using different fonts and colours for the boxes representing the main elements. The headlines in larger bold font indicate the broad, highly inclusive categories, and the green and blue fonts indicate the more specific categories that Western science and other knowledge systems, respectively, often use to refer to them. There is considerable debate about the terminology for what we here call western science on the one hand and other knowledge systems, in particular indigenous and local knowledge (ILK), on the other (see glossary[89] for definitions). Their use here is intended to be broad and indicative. Similarly, we acknowledge that western science and other knowledge systems are not necessarily mutually exclusive in character, content, and history [9,10]. Therefore the clear-cut distinction between the blue and green 'circuits' is largely operational, and a means to highlight the importance of incorporating diverse perspectives into the CF. A full alignment among the categories of different knowledge systems or even disciplines is unattainable, but every effort was made during the development of the CF to represent these alternative views. While a single CF has been retained for practical purposes, it is recognized that representations of human–nature relationships may vary across cultures and knowledge systems in relation to specific worldviews and cosmologies, including between scientific and indigenous knowledge systems, as well as among indigenous cultures. The CF is mainly intended to provide common ground, to facilitate cross-disciplinary and cross-cultural understanding and interoperability, and to identify options for action.

Six main elements to link people and nature

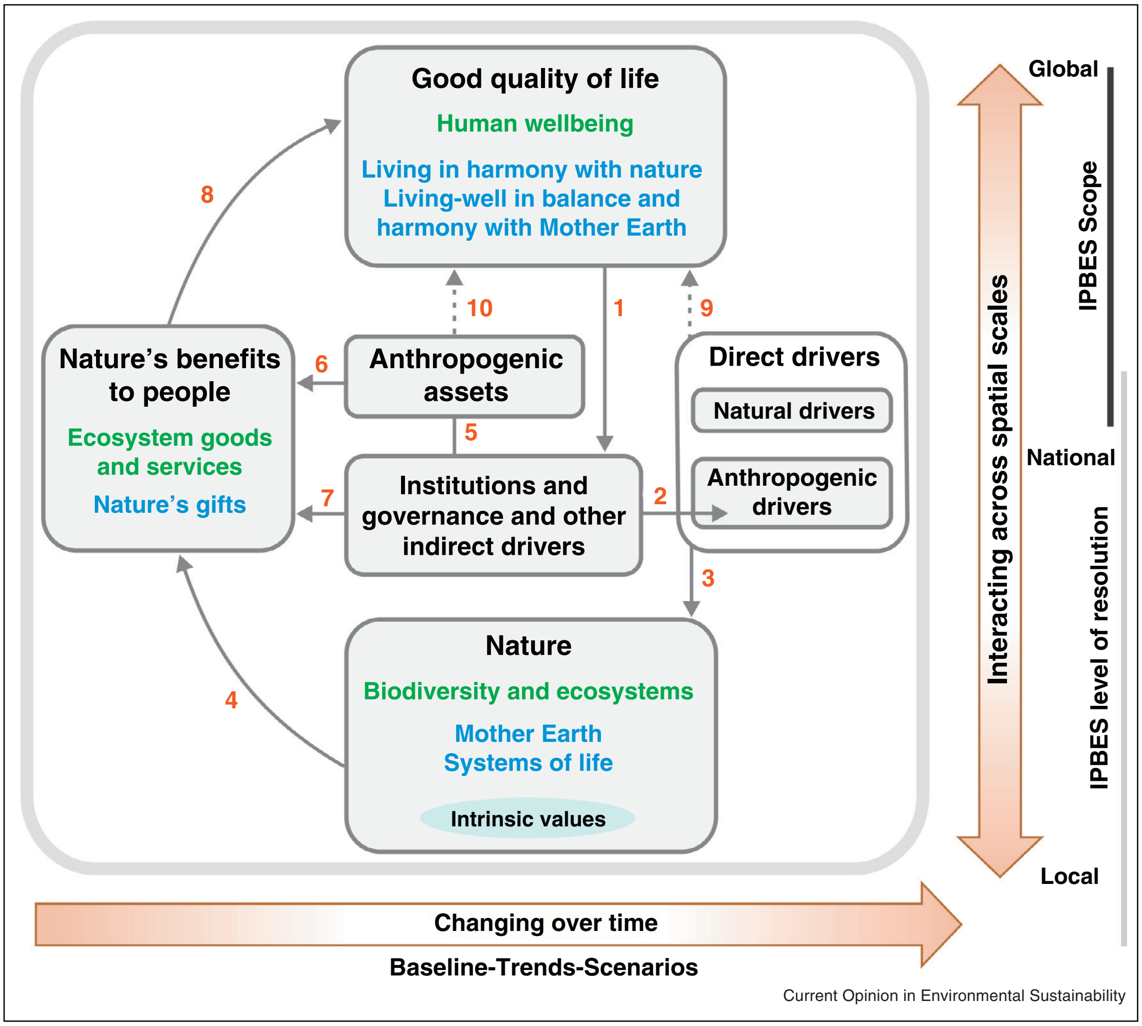
The CF includes six primary interlinked elements (or components) representing the natural and social systems that operate at various scales in time and space: *nature*; *nature's benefits to people*; *anthropogenic assets*; *institutions and governance systems and other indirect drivers of change*; *direct drivers of change*; and *good quality of life*[90] (Figure 1). These elements have been conceived as broad, inclusive categories with which all stakeholders should be able to relate. The six elements are described in detail below:

1. '*Nature*' in the context of IPBES refers to the natural world with an emphasis on the diversity of living organisms and their interactions among themselves and with their environment. Within the context of western science, it includes categories such as biodiversity, ecosystems, ecosystem structure and functioning, the evolutionary process, the biosphere, living natural resources (as defined in, e.g. Ref. [7]), shared evolutionary heritage [11,12•], and biocultural diversity [13,14] — which incorporates 'ethnobiodiversity' [15]. Being western science-based, these categories are indicated in green font within the *nature* box in Figure 1. Non-living natural resources which may benefit people and therefore contribute to a *good quality of life*, such as deep aquifers, mineral and fossil reserves, wind, solar, geothermal and wave power, are considered as part of *nature*, but their direct benefits (i.e. those that are not mediated by non-human living organisms) are not the focus of IPBES. Within the context of other knowledge systems, *nature* includes different categories and holistic concepts held by indigenous peoples around the world (in blue font). Examples are Mother Earth and systems of life, shared by the indigenous peoples of the South American Andes [16,17], the concepts of sēnluó-wànxiàng (vast forest and every manifestation of nature) and tien-ti (Heaven and Earth) of Taoism shared by East Asian peoples [18], and concepts of the land encompassing non-human living organisms, living people, ancestors, deities and their shared histories in the South Pacific Islands (e.g. fonua, vanua, whenua, ples) [15]. *Nature* has its own intrinsic values, independent from any human considerations of its worth or importance, and also contributes to societies through the provision of *benefits to people*, which have

[89] Definitions related to the specific context of the IPES Conceptual Framework; they may thus differ in detail from those used within individual disciplines.

[90] The inclusive names of the six elements of the CF are indicated in italics in the main text and in bold black font in Figure 1.

Figure 1



The IPBES Conceptual Framework (CF). In the central panel, delimited in grey, boxes and arrows denote the elements of nature and society that are at the main focus of the Platform. In each of the boxes, the headlines in black are inclusive categories that should be intelligible and relevant to all stakeholders involved in IPBES and embrace the categories of western science (in green) and equivalent or similar categories according to other knowledge systems (in blue). The blue and green categories mentioned here are illustrative, not exhaustive, and are further explained in the main text. Solid arrows in the main panel denote influence between elements; the dotted arrows denote links that are acknowledged as important, but are not the main focus of the Platform. Links indicated by numbered arrow are described in the main text (section on Linkages among the elements, and Box 2). The anthropocentric values of nature are embedded in the nature, nature's benefits to people and good quality of life boxes, and in the arrows connecting them. The intrinsic values of nature (represented by a blue oval at the bottom of the nature box) are independent from human experience and thus do not participate in these arrows (see Values section in main text for detailed explanation). The thick coloured arrows below and to the right of the central panel indicate that the interactions between the elements change over time (horizontal bottom arrow) and occur at various scales in space (vertical arrow). The vertical lines to the right of the spatial scale arrow indicate that, although IPBES assessments will be at the supranational-subregional to global-geographical scales (scope), they will in part build on properties and relationships acting at finer — national and subnational-scales (resolution, in the sense of minimum discernible unit). The resolution line does not extend all the way to the global level because, due to the heterogenous and spatially aggregated nature of biodiversity, even the broadest global assessments will be most useful if they retain finer resolution. This figure, modified from Ref. [78], is a simplified version of that adopted by the Second Plenary of IPBES [84]; it retains all its essential elements but some of the detailed wording explaining each of the elements has been eliminated within the boxes to improve readability.

anthropocentric instrumental and relational values (see Values section below).

2. '*Anthropogenic assets*' refers to built infrastructure, health facilities, knowledge (including ILK and technical or scientific knowledge, as well as formal and nonformal education), technology (both physical objects and procedures), and financial assets, among others. *Anthropogenic assets* have been highlighted to emphasize that a good life is achieved by a co-production of benefits between nature and various

assets built by people (see below). *Anthropogenic assets* are also important to include in the CF because the value of many of *nature's benefits to people* vary depending on the availability and preferences for alternative sources of those benefits. For example, the value of the vegetation and soils of watersheds in filtering water for drinking will be higher when there is no built alternative (e.g. a water filtration plant).

3. '*Nature's benefits to people*' refers to all the benefits that humanity — individuals, communities, societies, nations or humanity as a whole — in rural and urban settings — obtains from nature. Ecosystem goods and services — including provisioning, regulating and cultural services [8] — all fall in this category. Because they are categories from western science, they are indicated in green font in Figure 1. Analogous categories in other knowledge systems (indicated in blue font) include that of nature's gifts [16,19,20]. The importance of *nature's benefits to people* can be expressed through a diverse set of valuation approaches and methods (discussed further in the Values section below). The CF is inclusive of all of these value definitions and encourages broad consideration of the full suite of values in any assessment. As an illustration, an assessment that includes consideration of the value of bees would need to consider their diverse values. For example, bees provide pollination services that have monetary value in service to several of the main crops that feed the world, estimated at more than USD 200 billion per year [21]. In addition, bees can provide value via pollination of locally consumed crops, production of honey and other wild foods that are essential sources of nourishment and income more locally [22]. Furthermore, some pollinator species are part of indigenous and local communities' knowledge and management systems: for example, the rainforest and the open forest honey bees — dabu and walarr respectively — are two of the most important totemic species and form the basis of moieties and land classification for the Yalanji people of the Australian tropical rainforests [23]. Among the Maya, the stingless bees that are raised as part of an ancient practice are considered a gift from the gods [24]. Some of *nature's benefits to people* require no intervention (or minimal intervention) of society to be produced. For example, the production of oxygen and the contribution to the regulation of the Earth's temperature by photosynthetic organisms; the regulation of the quantity and quality of water resources by vegetation; coastal protection by coral reefs and mangroves; and the direct provision of food or medicines by wild animals, plants and microorganisms. Most of these benefits, however, depend for their provision on the joint contribution of *nature* and *anthropogenic assets* [25,26], in a process sometimes referred to as 'co-production' [25]. For example, some agricultural goods such as food or fibre crops depend on ecosystem processes such as soil formation, nutrient cycling, or primary production as well as on social intervention such as farm labour, knowledge of genetic variety selection and farming techniques, machinery, storage facilities and transportation. Trade-offs between the beneficial and detrimental effects of organisms and ecosystems are not unusual [27] and they need to be understood within the context of the bundles of multiple *benefits to people* provided within specific contexts [28]. In addition, what is beneficial, detrimental or value-neutral depends on the perspective and context of different societies, groups and even individuals [4,29]. The notion of *nature's benefits to people* includes detrimental as well as beneficial effects of *nature* on the achievement of a *good quality of life* by different people and in different contexts.

4. '*Institutions and governance systems and other indirect drivers*' are the ways in which people and societies organize themselves and their interactions with nature at different scales. They are the underlying causes of change that are generated outside the ecosystem in question (i.e. outside the *nature* box of Figure 1) and are central to the CF because of their crucial role, influencing all aspects of relationships between people and *nature*. Their effect can be positive or negative, either in absolute terms or context dependent. They are considered *indirect drivers* because in the vast majority of cases they do not affect *nature* directly, but rather through their effects on *direct anthropogenic drivers* (see below). Institutions encompass all formal and informal interactions among stakeholders and social structures that determine how decisions are taken and implemented, how power is exercised, and how responsibilities are distributed [30] Various collections of institutions come together to form governance systems, that include interactions between different centres of power in society (corporate, customary-law based, governmental, judicial) at different scales from local through to global [31]. Institutions and governance systems determine, to various degrees, the access to, and the control, allocation and distribution of components of *nature* and *anthropogenic assets* and their *benefits to people*. Examples of institutions are systems of property and access rights to land (e.g. public, common-pool or private), legislative arrangements, treaties, customary laws, informal social norms and rules, and international regimes such as agreements against stratospheric ozone depletion. Economic policies, including macro-economic, fiscal, monetary or agricultural policies, are institutions that play a significant role in influencing people's perception about the importance of *nature's benefits*, and their behaviour and thus decisions about the way they interact with nature. People, however, have diverse perspectives on a *good quality of life*, beyond the domain of wealth and income, to incorporate issues of justice, freedom, and equality.

Governance systems have different degrees of legitimacy and voice, performance, accountability, fairness and rights, and scale of operation [32,33]. The thorough consideration of different forms of institutions and decisions [34] and their role in altering connections with all other elements in the CF helps decision makers identify and test different policy options.

5. '*Direct drivers*', both natural and anthropogenic, affect nature directly. '*Natural direct drivers*' are those that are not the result of human activities and whose occurrence is beyond human control. These include natural climate and weather patterns, as well as extreme events such as prolonged drought or cold periods, tropical cyclones and floods, glacial lake outburst floods, earthquakes, volcanic eruptions and tsunamis. '*Anthropogenic direct drivers*' are those that are the result of human decisions and actions, namely, of *institutions and governance systems and other indirect drivers*. Some examples of *anthropogenic drivers* are degradation, exclusion and restoration of terrestrial and aquatic habitats, intensification or abandonment, harvesting of wild populations, climate change produced by anthropogenic carbon emissions, pollution of soil, water or air, and species introductions.
6. '*Good quality of life*' is the achievement of a fulfilled human life. Although what it entails varies considerably within and among different societies and cultures, everybody wants to be free from poverty and disease, have a long and fulfilling life, and access to freedoms and rights. It is a highly value-based and context-dependent state comprising multiple factors such as access to food, water, shelter, health, education, good social relationships, physical, energy and livelihood security, equity, cultural identity, material prosperity, spiritual satisfaction, freedom of choice, action and participation in society [35,36]. From virtually all standpoints, a *good quality of life* is multidimensional, having material, as well as non-material components. Reflecting the diversity of humankind, perceptions of a good life also vary with gender, age, and culture. Different societies, and different individuals within societies, have different views on desirable relationships with nature, the material versus the spiritual domain, and the present versus the past or future [36]. Because IPBES aims to embrace different knowledge systems and stakeholders, the consideration of differences and commonalities among these various visions on quality of life is particularly important. The three perspectives on *good quality of life* mentioned in the top box of Figure 1 — Human well-being, Living in harmony with nature and Living in balance and harmony with Mother Earth — illustrate this point. Human well-being (in green font) is a concept widely used in the international development field and is often defined as the state of physical and mental health of individuals. Common indicators of well-being used in national reports and by policy makers focus on material wealth or on synthetic measures such as the 'human development index' (HDI), but for IPBES, it is essential to embrace a broader definition such as suggested in the Millennium Ecosystem Assessment [7]. Initial indicators of human development, such as income and per capita gross domestic product (GDP), continue to be used by most countries. These indicators are important because average values per person per country are often correlated with child mortality, life expectancy and human development index, but they tend to capture only a small proportion of the many attributes of the current concept of human well-being of individuals. IPBES offers an opportunity to add to the above definitions and indicators the ethical and ecologically sustainable utilization of nature as key components of the concept of human well-being. A number of indicators covering the various aspects of well-being are now available, including genuine progress indicator, inclusive wealth index, the gross national happiness index pioneered by Buthan, OECD good life indicator, and the coefficient of living standard among others [37•,38•,39•]. Other knowledge systems or cultural traditions relate more meaningfully to perspectives on a *good quality of life* that show both differences and commonalities with that of human well-being, and are indicated in blue font. For example, the concept of Living in harmony with nature — which was initially presented in international discourse at the United Nations in 1982, but then largely ignored until recently — has been adopted as vision by the Convention on Biological Diversity and used in its Strategic Plan for Biodiversity 2011–2020 and the Aichi Targets (http://www.cbd.int/decision/cop/?id=12268). This concept appears already in early colonial sources describing indigenous populations in the Andes [40]. Over time, it has come to highlight the interdependence that exists among human beings, other living species and the elements of nature. It implies that we should live together with all other organisms respectfully even though we need to exploit some of these organisms to a certain degree. This concept was originally proposed to the Convention on Biological Diversity by Japan. The original Japanese term (shizen kyosei shakai) literally means society in symbiosis — or living together — with nature, not only with mutual benefit but also with relationships which are necessarily detrimental for one of the parties, but which should be made sustainable [41]. Likewise, Living-well in balance and harmony with Mother Earth is a concept originating in the vision of many indigenous peoples worldwide, has been recently incorporated in the legal framework of some Latin American countries [16,19], and emphasizes the collective cosmocentric relationships across time among people and between people and Mother Earth. Balance and harmony refers

to individuals in the context of a wider human community, including ancestors and descendants, and also between humans and Mother Earth, which is seen as a holistic entity that sustains all living things, and of which humans are an inextricable part, physically and spiritually. In this vision, Mother Earth is entitled with rights as a collective subject of interest (http://www.cbd.int/decision/cop/?id=12268) [17]. It is evident that there are wide overlaps as well as differences in the perspectives on a *good quality of life* across various knowledge systems, cultures and societies. Thus, efforts are needed to develop a common ground to understanding how to achieve the various visions of a *good quality of life* while pursuing the conservation and sustainable use of *nature* and its *benefits to people* at different scales.

Linkages among the elements

Among the complex interactions that link the six elements described in the previous section, the CF focuses on those that are directly relevant to the goal of IPBES. These relationships are indicated by arrows in the main panel of Figure 1, generically described here, and illustrated by an example in Box 2. A society's achievement of *good quality of life* and the vision of what this entails directly influence *institutions and governance systems and other indirect drivers* (Arrow 1 in Figure 1) and, through them, they influence the other elements of the CF. For example, to the extent that a good life refers to an individual's immediate material satisfaction and individual rights, or to the collective needs and rights of present and future generations, it affects institutions that operate from the subnational scale, such as land and water use rights, pollution control, and traditional arrangements for hunting and extraction, to the global scale, as in subscription to international treaties or biosecurity protocols. Views of what constitutes a *good quality of life* also indirectly shape, via institutions, the ways in which individuals and groups relate to *nature*. Perceptions of *nature*, for example, may range from *nature* being considered as a resource to be exploited for the benefit of human societies, to *nature* being seen as a sacred living entity of which humans are only one part.

Institutions and governance systems and other indirect drivers affect all elements and are the root causes of the *direct anthropogenic drivers* that affect *nature* (Arrow 2). For

Box 2 An example of application of the CF: Marine wild fisheries

There are more than 28 000 fish species recorded in 43 ecoregions in the world's marine ecosystems and probably still many more to be discovered (*nature*). With a worldwide network of infrastructure such as ports and processing industries, and several million vessels (*anthropogenic assets*), about 80 million tons of fish are caught every year [85] (Arrow 6). Fish are predicted to become one of the most important items in the food supply (*nature's benefits*; Arrow 4) of over seven billion people [85]. This is an important contribution to the animal protein required to achieve food security (*good quality of life*) (Arrow 8).

Campaigns and promotion of the benefits of fish protein have induced changes in consumption patterns (Arrow 8) and have brought about an improvement in the diet (*good quality of life*), and an increased demand for fish in the global markets (Arrow 1). This, together with the predominance of private short-term interests over collective long-term interests, weak regulation and enforcement of fishing operations, and perverse subsidies for diesel, are *indirect drivers* underlying (Arrow 2) the exploitation of fisheries by fishing practices (*anthropogenic direct drivers*) that, because of their technology or spatial scope or time scale of deployment, are destructive to fish populations and their associated ecosystems (Arrow 3). The impacts of these practices are combined with those of other *anthropogenic direct drivers* in affecting marine biodiversity (*nature*) directly (Arrow 3). These drivers include chemical pollution associated with agriculture and aquacultural runoff, the introduction of invasive species, diversions and obstructions of freshwater flows into rivers and estuaries, the mechanical destruction of habitats, such as coral reefs and mangroves, and climate and atmosphere change, including ocean warming and acidification.

The steep decline in fish populations can dramatically affect other components of *nature*, in the form of wildlife, ecological food webs, including those of marine mammals and seabirds, and ecosystems from the deep sea to the coast. Increasingly depleted fisheries also have negative consequences for many societies in the form of decreases in catches (*nature's benefits to people*; Arrow 4), loss of fish species that have high ceremonial value *nature's benefits to people* and *good quality of life*), reduced access (Arrow 8), and the impaired viability of commercial and recreational fishing fleets and associated industries across the globe *(anthropogenic assets*). In the case of many small-scale fisheries in less developed countries, this disproportionally affects the poor and women (*quality of life*) [86]. Decreases in catches by small-scale fisheries can indirectly affect *nature* and its *benefits to people* and *quality of life* well beyond coastal areas, for example, by increasing bushmeat harvest in forest areas as an alternative source of protein, and thus affecting populations of wild mammals such as primates, and posing threats to human health [87]. In many cases, lack of recognition of the *formal and informal institutions* of indigenous and local peoples and their customary marine tenure systems is a further *indirect driver* that leads to the overriding of these systems by practices that supply fish to the global economy (Arrows 2, 5, 6, and 7).

Institutions and governance systems and other indirect drivers can be mobilized to halt these negative trends and foster the recovery of many depleted marine ecosystems (*nature*), fisheries (*nature's benefits to people*) and their associated food security and lifestyles (*good quality of life*). Examples include strengthening and enforcement of existing fishing regulations, such as the Code of Conduct for Responsible Fisheries of the Food and Agriculture Organization of the United Nations [88], helping people diversify their livelihoods to reduce total fishing effort and improve wield, the zoning of the oceans into reserves and areas with different levels of catch effort, enhanced control of quotas and pollution, preservation of cultural norms that avoid overexploitation of ecologically important fish species, and recognition of indigenous and local peoples' customary marine tenures and sustainable use systems. In addition, *anthropogenic assets* could be mobilized towards this end in the form of the development and implementation of new critical knowledge, such as fishing gear and procedures that minimize by-catch, or a better understanding of the role of marine reserves and no-catch areas in the long-term resilience of exploited fisheries.

example, economic and demographic growth and lifestyle choices (*indirect drivers*) influence the amount of land that is converted and allocated to food crops, energy crops or plantations; accelerated carbon-based industrial growth over the past two centuries has led to anthropogenic climate change at the global scale; synthetic fertilizer subsidy policies have greatly contributed to the detrimental nutrient loading of freshwater and coastal ecosystems. All of these have strong effects on biodiversity, ecosystem functioning and their derived benefits and, in turn, influence different social arrangements intended to deal with these problems. This may be seen, for example, at the global level, with institutions such as the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity, the Convention on the Conservation of Migratory Species of Wild Animals or, at the national and subnational levels, arrangements in ministries or laws that contribute to the protection, restoration and sustainable management of biodiversity.

Institutions and governance systems and other indirect drivers also affect the interactions and balance between *nature* and *anthropogenic assets* (Arrows 5, 6, and 7) in the co-production of *nature's benefits to people*, for example, by regulating urban sprawl over agricultural or recreational areas. This element also modulates the link between *nature's benefits to people* and the achievement of *a good quality of life* (Arrow 8), for example, by different regimes of property and access to land and goods and services; transport and circulation policies; and economic incentives as taxations or subsidies. The links between *nature* and *anthropogenic assets* are sometimes negative. For example, the deployment of technology and infrastructure typically associated with urbanization, expansion of road networks, industry and large-scale agriculture are often detrimental to *nature* (see more examples in Box 2). In this sense, the same piece of agricultural machinery, or the same vessel, can be conceptualized as part of the *anthropogenic assets* that together with *nature* co-produce a *benefit to people* (e.g. grains or fish respectively), or as an instrumental part of a *direct anthropogenic driver* (e.g. land conversion, or direct exploitation, respectively) that affects *nature*. However, in many cases *anthropogenic assets* (including knowledge systems and physical practices) create and maintain biodiversity. Examples are the numerous cultivated varieties of rice, potatoes, maize and other crops obtained from wild relatives and maintained by ancestral agricultural societies in Africa, Asia, Latin America and the Pacific Islands [42,43], the highly diverse meadows and pasturelands maintained by traditional pastoral use in Europe [44], and the high heritage and economic value ascribed to nature and eco-tourism initiatives in many African countries [45]. Many cultures around the world also have spiritual and religious practices in which certain places, water bodies, forests, animals, trees are considered sacred, serve as totems, are protected by rituals and taboos, and/or are revered as gifts imbued with ancestral and divine presence and significance [46,47]. Different societies, rural and urban, experience different elements of the natural world (different animals, different vegetation types, different seasonal and decadal cycles); and they do so with different immediacy (from everyday intimate contact to sporadic contact through *the* mass communication media). These are important factors shaping their perspectives on the reciprocal relationship between nature and a *good quality of life* [48,49].

Direct drivers of change are the immediate cause of changes in *nature* (Arrow 3) and, as a consequence, affect the supply of *nature's benefits to people* (Arrow 4). *Natural drivers* affect *nature* directly, for example, the climatic regime is one of the most important factors determining the distribution of ecosystems and biomes on Earth [50], and the impact by a massive meteorite is believed to have triggered one of the mass extinctions of plants and animals in the history of life [51]. Furthermore, a volcanic eruption can cause ecosystem destruction, while at the same time serving as a source of new rock materials for fertile soils [52]. *Direct drivers* also affect *anthropogenic assets* directly (arrow not shown), for example, when housing or water and power supply systems are disrupted by earthquakes or hurricanes. *Direct drivers* can also have direct impacts on the *quality of life* (Arrow 9), including health problems directly associated with particularly harsh climates, heat stroke as a result of climate warming, poisoning as a result of pollution, or death as a result of a tsunami.

In addition to their effect through Arrows 6 and 7 (see above), *anthropogenicassets* directly affect the possibility of achieving a *good quality of life* through the provision of and access to material wealth, shelter, health, education, satisfactory human relationships, freedom of choice and action, and sense of cultural identity and security (Arrow 10). These linkages are acknowledged in Figure 1 but not addressed in depth because they are not the main focus of IPBES when they by-pass *nature's benefits to people*. These links, however, need to be considered when assessing the importance of *nature's benefits to people* as the relative availability of *anthropogenic assets* influences how people perceive the importance of benefits from nature (see section on *Anthropogenic assets* above).

Application across scales

The processes described in the previous sections occur and interact at different scales and management levels (indicated by the thick arrows outside the central panel of Figure 1). The CF can thus be simultaneously applied locally, regionally and globally to, for example, different scales of ecological processes and scales of potential drivers of change. The evidence so far suggests that causal links between *nature* and *benefits to people* are strongly scale-dependent, and also straddle over several scales [53•]. Such a multi-scale and cross-scale perspective also supports the identification of tradeoffs within scales, such as between different policy sectors, and across scales, by making clear how *nature's benefits to people* can be supplied, used, valued and managed at different spatial and temporal scales, as well as interactions and feedback from many factors which can also function at multiple scales [33].

IPBES will focus on supranational (subregional, regional or continental) to global geographical scales for assessment. However, the properties and relationships that occur at these coarser spatial scales will, in part, be linked to properties and relationships acting at finer scales, such as national and subnational scales. Linking these scales will be a key challenge for IPBES assessments; the CF can support understanding of interactions over various temporal, spatial and management scales [53•]. Some interactions may happen very fast, others more slowly, and there is often a correspondence between the space and time scales [50]. For example, changes in the chemical composition of the atmosphere and the oceans often occur over centuries or millennia, whereas changes in biodiversity as a consequence of land use change at the landscape scale often occur at the scale of years or decades. Processes at one scale often influence, and are influenced by processes that occur at other scales. Because of this, assessments will benefit from contemplating the mutual influences, such as control and propagation, between the scale that is the focus of the assessment and finer and coarser scales. Assessments at multiple scales are also recommended as a means to better represent complex interactions across scales.

The conceptual framework serves as a starting point for the analysis of institutional arrangements and ecosystem boundaries at different scales. Understanding the mismatch between ecosystems and institutional arrangements is particularly critical at when political and administrative boundaries cut across environmental systems, such as watersheds, bio-geo-cultural regions or the territories of nomadic or seminomadic peoples [33,54,55]. Such understanding supported by the conceptual framework will provide policy-relevant advice at supranational and subnational scales. For instance, in gathering knowledge from, and providing options to policy and decision making at all levels, IPBES might address institutions at global (e.g. Multilateral Environmental Agreements and their financial mechanisms), regional (e.g. New Partnership for Africa's Development, European Union, Association of Southeast Asian Nations and Mercosur), national (e.g. national environmental protection agencies, ministries of finance, agriculture and health) and subnational/ local (e.g. province, state, above-local coherent landscape units, city or village) scales.

Validation in the context of the IPBES Conceptual Framework

Mutual recognition and enrichment among different disciplines and knowledge systems is an essential goal of IPBES. The stated goal of IPBES explicitly mentions the interface between science and policy, it is understood that the term 'science' in this denotes a broader concept that includes contributions not only from natural, social and engineering disciplines within western science, but also from knowledge of indigenous and local community stakeholders and practitioners. All these knowledge systems can work in complementary and mutually enriching ways. This poses a challenge for validation (i.e. how a portion of knowledge achieves legitimacy, or how assessments ensure they interpret and present ILK correctly), due to the different principles and criteria that operate across knowledge systems and across disciplines within western science.

Some authors [56,57•] have proposed a Multiple Evidence Based (MEB) approach to address this challenge. Such an approach acknowledges that there are aspects of each knowledge system — or even discipline, for example, social and natural sciences — that cannot be fully translated from one into another. It also emphasizes the need for co-production through the engagement different stakeholders, such as scientists from different disciplines, practitioners and disseminators, and ILK holders. The MEB approach highlights the complementarity, synergy and cross-fertilization of knowledge systems, rather than the integration of one system into another. It also stresses that relevant stakeholders should be involved at all stages in the processes of knowledge generation, assessment, design of policy support tools and capacity building. Such involvement should include the critical steps of definition of goals, scoping of problems and tasks, and examination and adaptation of findings.

Each knowledge system has its own processes of validity. Communities will often recognize that valid knowledge comes from certain knowledge holders: person/s with the rights (e.g. gender, title-holding) and skills (e.g. language, farming). Valid knowledge in ILK systems is tested and retested through practice, for example, the application of medicinal plants, or the use of materials in fishing [31]. The most important validity issue for ILK holders is often that of ensuring that the inclusion and interpretation of their knowledge and information in processes outside of their cultural context is robust in terms of their knowledge and belief systems [58].

The meaningful engagement of different knowledge systems will undoubtedly increase the richness and usefulness of the IPBES assessments and at the same time adds to the complexity of the task at hand [58]. Cross-fertilization and co-construction of knowledge is relatively common at the local to subnational scales, but still rare at coarser scales (e.g. regional, global). The development of new ways of achieving this would be a major contribution of the IPBES process. Valuable lessons for the construction of MEB processes within IPBES can be drawn from existing initiatives such as Japan's Satoyama Satoumi [59] (http://collections.unu.edu/view/UNU:1508), the Community Based Monitoring and Information Systems spearheaded by the International Indigenous Forum on Biodiversity (http://iifb.indigenousportal.com/), the assessments carried out by the multiple-stakeholder Arctic Council (http://www.arctic-council.org/), and the Fiji Locally Managed Marine Areas Network of community-managed marine areas (http://lmmanetwork.dreamhosters.com/fiji).

Values and valuation of nature and its benefits to people

The inclusive nature of the CF, in terms of benefits, stakeholders, knowledge systems and worldviews, necessarily requires the consideration of multiple value systems. Value systems vary among individuals within groups, and across groups at various temporal and spatial scales (e.g. some nations tend to be more dominated by value systems that prioritize individual rights and others by value systems that prioritize collective and community-level values) [60]. The many ways of classifying and naming values, and methods for describing them, have been discussed extensively elsewhere [6,61–66] and are beyond the scope of this article. In this section we thus provide a general outline of various approaches to and uses of the term 'value' which are important in the context of the CF and more generally in the work of IPBES.

A necessary first step is to distinguish between different uses of the term 'value'. This can refer to the 'importance, worth or usefulness' as well as to 'held values, principles or moral duties'. Both of these notions of value are pertinent to *nature* and its *benefits to people* as the held values of individuals and groups (e.g. fairness, truthfulness, fidelity, as in 'the values instilled by one's parents') are incorporated within institutions, conforming the basis of a society's culture. In addition, these held values help determine which things a society perceives as being important, beneficial or useful. Both values contribute to achieve a *good quality of life*.

A major distinction adopted in the CF is between intrinsic values and anthropocentric values, including instrumental and relational values. Intrinsic values are those inherent to *nature*, independent of human judgement, such as non-human species' inherent rights to exist. Intrinsic values of *nature* as defined here have no relationship with possible benefits to humans or their quality of life; they thus fall outside the scope of anthropocentric values and valuation methods. Within anthropocentric values, instrumental values are closely associated with the notion of *nature's benefits* as far as they allow people to achieve a *good quality of life*, be it through spiritual enlightenment, aesthetic pleasure or the production or consumption of a commodity. They can be linked to economic values (including, but not restricted to monetary valuation) as they reflect the extent to which they confer satisfaction to humans either directly or indirectly [62]. Relational values, on the other hand, are imbedded in desirable (sought after) relationships, including those between people and *nature* (as in 'living in harmony with nature') [67], or biophilia [68], regardless of whether those relationships imply tradeoffs to obtain *nature's benefits*, and therefore they depart from an economic valuation framework [69•]. Relational values are also related to the notion of held values because specific principles or moral duties can determine how individuals relate with *nature* and with other individuals.

Therefore, all *nature's benefits to people* have instrumental values and relational values, and often a given aspect of *nature* (a species, an ecosystem, a network of ecological interactions) can provide more than one *benefit to people*, with different instrumental and relational values. These two broad categories of values can be expressed in diverse ways within the CF as they can be experienced in a non-consumptive way (both relational and instrumental values) or through consumption (specific instrumental values), and they can range from spiritual inspiration (both relational and instrumental values) to market-based values (specific instrumental values). They also include existence value (the satisfaction obtained from knowing that nature continues to be there) and future-oriented values. These future-oriented values include bequest value — the preservation of nature for future generations — and the option values of biodiversity as a reservoir of yet-to-be discovered uses from known and still unknown species and biological processes, and as a constant source, through evolutionary processes, of novel biological solutions to the challenges of a changing environment [11].

Many techniques have been developed to estimate instrumental values from an economic perspective and are used at various scales. However, a debate exists as to whether the biodiversity and ecosystem services values can be aggregated into only one metric, e.g. the monetary one [70,71], whether *nature per se* can or should be valued with such techniques; and how to value the role of biological diversity itself as this is multi-layered and therefore hard to evaluate [60,61,64,72•,73]. Evaluating and communicating economic values using a monetary metric can help spread awareness to policymakers and lay people, and help identify social welfare-enhancing decisions and actions regarding conservation of *nature* and its *benefits to people*, especially when dealing with ecosystem goods and services at local scales and short time horizons, and where the market system is commonplace; this is the case of many provisioning services. But in many situations, when dealing with more complex services such as regulating or cultural services, such valuation may neither be appropriate nor necessary nor sufficient nor practical [60,62,74]. For example, farmers who cherish an agricultural way of life as part of their cultural heritage may feel that these values cannot be captured monetarily. The provision of clean drinking water by vegetated watersheds is seen by some cultures as an entitlement and not a commodity, thus being beyond the market logic [60]. Sacred groves have been protected for millennia based on value systems that hold as sacred particular pieces of forest, supported by taboos about their use [47]. It is questionable whether the monetary valuation of such benefits would be helpful in maintaining them.

Whatever the approach chosen, valuation approaches and techniques need to fit with the value system of all stakeholders involved to make sure that their preferences, interests, perceptions of *nature*, and ideas of what would be the legacy to future generations are considered [4,26]. Pairing different value systems with different valuation approaches and techniques can provide an integrated value map of *nature's benefits*. This in turn is necessary to identify how policy tools can minimize potential value conflicts across stakeholders and thus enable to take into account the trade-offs between an efficient allocation of nature's benefits and their equitable distribution across stakeholders [26,75•].

In summary, multiple valuations may help identify a set of decisions, embedded within an institutional context. This can lead to a *good quality of life* by supporting the flow of *nature's benefits to people*. The more valuation can reflect the value systems embedded in formal and informal institutions of the involved stakeholders, and the more it can appropriately characterize the distribution of the costs and benefits of proposed actions or policies (across time, space and stakeholders), the more useful it is likely to be [76,77]. Valuation frameworks applicable to diverse socio-cultural contexts would be a major contribution by IPBES to the knowledge-policy interface.

The way ahead

The CF presented in this article is a drastically simplified representation of the links between very heterogenous constellation of societies and an overwhelmingly diverse natural world, We argue that such degree of simplification is justified by the interdisciplinary and cross-cultural understanding required by the unprecedented intent of IPBES to bring together the perspectives and information of a wide spectrum of knowledge systems and stakeholders on the status and trends of the living world and its benefits to people, what to do about them now and what to expect in the future. Within this context, the CF has been considered a 'Rosetta Stone' [78] to enable 'translating' basic concepts and facilitating communication, and assisting the formulation of fundamental understanding that is transparent, salient, credible and legitimate to all parties involved [79].

IPBES explicitly aims to inform policy and practice. By helping identify the essential elements and interactions that are the causes of and solutions to detrimental changes in biodiversity and ecosystems and subsequent loss of their benefits to present and future generations, the CF should also contribute to positive transformation [80].

Considering that the focus on co-design and con-construction of integrative knowledge around complex problems is shared by an increasing number of initiatives [81–83], the CF has the potential to be useful beyond the scope of IPBES. Whether it will have a major influence on the scientific research and knowledge-policy arenas will be tested by practice.

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Glossary

Anthropogenic assets: Built-up infrastructure, health facilities, knowledge (including indigenous and local knowledge systems and technical or scientific knowledge, as well as formal and non-formal education), technology (both physical objects and procedures), and financial assets among others.

Baseline: A minimum or starting point with which to compare other information (e.g. for comparisons between past and present or before and after an intervention).

Biocultural diversity: Biocultural diversity, defined as the total variety exhibited by the world's natural and cultural systems, explicitly considers the idea that culture and nature are mutually constituting, and denotes three concepts: Firstly, diversity of life includes human cultures and languages; secondly, links exist between biodiversity and cultural diversity; and finally, these links have developed over time through mutual adaptation and possibly co-evolution. Biocultural diversity incorporates ethnobiodiversity.

Biodiversity (contraction of biological diversity): The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems.

Biosphere: All the ecosystems of the world considered together. It includes the organisms living on the Earth, the resources they use and the space they occupy on part of the Earth's crust (the lithosphere), in the oceans (the hydrosphere) and in the atmosphere.

Cosmocentric: A vision of reality that places the highest importance or emphasis in the universe or nature, as opposite to and anthropocentric vision, which strongly focuses on humankind as the most important element of existence.
Drivers: Natural or anthropogenic (human-induced) factor that directly or indirectly causes a change in nature.
Drivers, anthropogenic direct: Direct drivers that are the result of human decisions, namely, of institutions and governance systems and other indirect drivers.
Drivers, direct: Drivers (both natural and anthropogenic) that operate directly on nature (sometimes also called pressures).
Drivers, indirect: Drivers that operate by altering the level, direction or rate of change of one or more direct drivers.
Drivers, institutions and governance and other indirect: The ways in which societies organize themselves. They are the underlying causes of environmental change that are external to the ecosystem in question, on which they operate through direct drivers.
Drivers, natural direct: Direct drivers that are not the result of human activities and are beyond human control.
Ecosystem: A dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit Ecosystems can be defined at a variety of scales, from a single pond to the globe. Humans and their activities are part of ecosystems as well.
Ecosystem functioning: The flow of energy and materials through the arrangement of biotic and abiotic components of an ecosystem. It includes many processes such as biomass production, trophic transfer through plants and animals, nutrient cycling, water dynamics and heat transfer. The concept is used here in the broad sense and it can thus be taken as being synonymous with ecosystem properties or ecosystem structure and function.
Ecosystem services: The benefits (and occasionally losses or detriments) that people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; and cultural services such as recreation, ethical and spiritual, educational and sense of place. In the original definition of the Millennium Ecosystem Assessment the concept of 'ecosystem goods and services' is synonymous with ecosystem services. Other approaches distinguish 'final ecosystem services' that directly deliver welfare gains and/or losses to people through goods from this general term that includes the whole pathway from ecological processes through to final ecosystem services, goods and anthropocentric values to people.
Ecosystem goods: According to the Millennium Ecosystem Assessment, they are included in the general definition of ecosystem services. According to other approaches, they are objects from ecosystems that people value through experience, use or consumption. The use of this term in the context of this document goes well beyond a narrow definition of goods simply as physical items that are bought and sold in markets, and includes objects that have no market price.
Ethnobiodiversity: The uses, knowledge, beliefs, management systems, taxonomies and language that a given culture has for the biodiversity with which it relates (ecosystems, species and genetic diversity). Ethnobiodiversity is part of biocultural diversity.
Good quality of life: The achievement of a fulfilled human life, the criteria for which may vary greatly across different societies and groups within societies. It is a context-dependent state of individuals and human groups, comprising aspects such access to food, water, energy and livelihood security, and also health, good social relationships and equity, security, cultural identity, and freedom of choice and action. 'Living in harmony with nature', 'living-well in balance and harmony with Mother Earth' and 'human well-being' are examples of different perspectives on good quality of life.
Human well-being: See well-being.
Indigenous and local knowledge system (ILK): A cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment. It is also referred to by other terms such as, for example, Indigenous, local or traditional knowledge, traditional ecological/environmental knowledge (TEK), farmers' or fishers' knowledge, ethnoscience, indigenous science, folk science.
Institutions: Encompass all formal and informal interactions among stakeholders and social structures that determine how decisions are taken and implemented, how power is exercised and how responsibilities are distributed.
Knowledge system: A body of propositions that are adhered to, whether formally or informally, and are routinely used to claim truth.
Level of resolution: Degree of detail captured in an analysis. A high level of resolution implies a highly detailed analysis, usually associated with finer spatial and temporal scales. A low level of resolution implies a less detailed analysis, usually associated with coarser spatial and temporal scales.
Living in harmony with nature: A perspective on good quality of life based on the interdependence that exists among human beings, other living species and elements of nature. It implies that we should live peacefully alongside all other organisms even though we may need to exploit other organisms to some degree.
Living-well in balance and harmony with Mother Earth: A concept originating in the visions of indigenous peoples worldwide which refers to the broad understanding of the relationships among people and between people and Mother Earth. The concept of living-well refers to: Firstly, balance and harmony of individuals considering both the material and spiritual dimensions; secondly, balance and harmony among individuals taking into account the relationship of individuals with a community; and finally, balance and harmony between human beings and Mother Earth. Living-well means living in balance and harmony with everybody and everything, with the most important aspect being life itself rather than the individual human being. Living-well refers to living in community, in brotherhood, in complementarity; it means a self-sustaining, communitarian and harmonic life.
Mother Earth: An expression used in a number of countries and regions to refer to the planet Earth and the entity that sustains all living things found in nature with which humans have an indivisible, interdependent physical and spiritual relationship.
Nature: The natural world, with emphasis on the diversity of living organisms and their interactions among themselves and with their environment.
Nature's benefits to people: All the benefits (and occasionally losses or detriments) that humanity obtains from nature.
Policy tools: Instruments used by governance bodies at all scales to implement their policies. Environmental policies, for example, could be implemented through tools such as legislation, economic incentives or dis-incentives, including taxes and tax exemptions, or tradable permits and fees.
Scenarios: Plausible alternative future situations based on a particular set of assumptions. Scenarios are associated with lower certainty than projections, forecasts or predictions. For example, socio-economic scenarios are frequently based on storylines describing several alternative, plausible trajectories of population growth, economic growth and per capita consumption, among other things. These are commonly coupled with projections of impacts on biodiversity and ecosystem services based on more quantitative models. The term 'scenarios' is sometimes used to describe the outcomes of socio-economic scenarios coupled with models of impacts, owing to the high uncertainty associated with the socio-economic trajectories.
Systems of life: The complex, integrated interactions of living beings (including humans), such as the cultural attributes of communities, socio-economic conditions and biophysical variables.
Trend: The general direction in which the structure or dynamics of a system tends to change, even if individual observations vary.
Values: Those actions, processes, entities or objects that are worthy or important (sometimes values may also refer to moral principles).
Values, bequest: The satisfaction of preserving the option of future generations to enjoy nature and its benefits.

Values, existence: The satisfaction obtained from knowing that nature endures.
Values, instrumental: The direct and indirect contributions of nature's benefits to the achievement of a good quality of life. Within the specific framework of the Total Economic Value, instrumental values can be classified into use (direct and indirect use values) on the one hand, and non-use values (option, bequest and existence values) on the other. Sometimes option values at considered as use values as well.
Values, intrinsic: The values inherent to nature, independent of human judgement, and therefore beyond the scope of anthropocentric valuation approaches.
Values, option: The potential ability to use some nature's benefits in the future, although they are not currently used or the likelihood for their future use is low. It represents the willingness to preserve an option for the future enjoyment of known or yet unknown nature's benefits. The 'option values of biodiversity', that is, the value of maintaining living variation in order to provide possible future uses and benefits, often used within the context of conservation biology, is included in this broad concept.
Values, relational: The values that are imbedded in desirable (sought after) relationships, including those among people and between people and nature; because such relationships are valued regardless of whether they imply tradeoffs to obtain *nature's benefits*, relational values depart from economic valuation frameworks.
Value systems: Set of values according to which people, societies and organizations regulate their behaviour. Value systems can be identified in individuals and social groups and thus families, stakeholder groups and ethnic groups may be characterized by specific value systems.
Well-being: A perspective on a good life that comprises access to basic materials for a good life, freedom and choice, health and physical well-being, good social relations, security, peace of mind and spiritual experience.
Western science: (Also called modern science, Western scientific knowledge or international science) is used in the context of the CF as a broad term to refer to knowledge typically generated in universities, research institutions and private firms following paradigms and methods typically associated with the 'scientific method' consolidated in Post-Renaissance Europe on the basis of wider and more ancient roots. It is typically transmitted through scientific journals and scholarly books. Some of its central tenets are observer independence, replicable findings, systematic scepticism, and transparent research methodologies with standard units and categories.

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