HOW NATURAL CAPITAL ACCOUNTING FRAMEWORKS FAIL ECOSYSTEM SERVICES

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ABSTRACT

The United Nations (UN) System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA – EA, UN 2021) has the potential to provide decision-makers with valuable information about the economic value of ecosystems and their components. However, the system has several shortcomings that must be addressed. The need for hard data, the focus on economic value over ecological value and integrity, the reliance on monetary valuation and the lack of clear guidance on the integration of the monetary values into decision-making processes and policies, are some of the issues that must be addressed for the framework to be an effective tool for promoting sustainable management of ecosystems. This is especially important because the ultimate goal of this exercise is to mitigate climate change and to protect biodiversity; to maintain a liveable planet for future generations by focusing on the valuation and accounting for ecosystem services provided by natural capital. Options to improve the system, as well as an alternative model, are briefly discussed. However, our fear is that the system in use is rapidly becoming too academic, too complicated, too time consuming and too easy to be controlled by some in the financial sector. The protection and restoration of ecosystems should not depend on highly complicated bookkeeping systems that may take some more years to finalize and many years to implement, but it does require urgent and collective action to reduce emissions and put a halt to ecosystem degradation, biodiversity loss and climate change – namely a collective change in attitudes and a complete revision of existing economic theories.

Keywords: biodiversity; climate change; complexities; economic bias; integrity

Introduction

The United Nations (UN) System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA – EA, UN 2021) constitutes an integrated and comprehensive statistical framework for organizing data about habitats and landscapes, tracking changes in ecosystem assets and the ecosystem services they provide, and linking this information to economic and other human activity (SEEA EA 2021). Ecosystem services refer to the benefits that humans obtain from the natural environment, such as clean air and water, carbon sequestration, pollination, food, flood control, and cultural and recreational opportunities. Thus, the framework provides a method for valuing and accounting for ecosystem services that support human existence, well-being and economic activity, and involves quantifying the value of these benefits in monetary terms and incorporating them into economic decision-making.

It was expected that translating the value of ecosystem services into monetary terms and connecting this to the systems of national accounts would help to make the value of these services more easily understood by enabling a comparison with more familiar goods and services. It was anticipated this would make it less difficult for decision makers to justify investments in healthy ecosystems, protected areas and restoration of degraded ones, as the benefits can be quantified and evaluated in the same terms as other economic activities. Additionally, monetary valuation could also help with cost-benefit analyses and to identify trade-offs and opportunities for cost-effective conservation and management of ecosystems.

The main advantage of the UN ecosystem accounting framework (SEEA – EA, UN 2021) is that it provides a common language and methodology, promoting international consistency and comparability, while helping to raise awareness and understanding of the importance of investing in protected areas and other ecosystems to mitigate climate change, protect biodiversity and to maintain a liveable planet for future generations.

The need for a common language is emphasised by the development of the UN Sustainable Development Goals (SDGs) (UN 2015), in which all UN member states agreed to incorporate the values of ecosystems and biodiversity into national planning and accounts by 2020 (Bordt and Saner 2018). The usefulness of the SEEA EA (UN 2021) as an instrument to mainstream ecosystems and biodiversity into national planning processes is explicitly recognised via SDG Indicator 15.9.1, "Progress towards national targets established in accordance with Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011–2020", which in part B requires the "integration of biodiversity values into national accounting and reporting systems, defined as implementation of the SEEA" (CBD).

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Numerous ecosystem accounting frameworks have been proposed and several are currently in use, but in this communication, we will primarily focus on the most widely applied framework – that developed by the UN through the SEEA – EA (UN 2021) and its use in the Netherlands.

Although we do not claim to be experts on ecosystem accounting frameworks, when scanning the most recent iteration of the UN framework (SEEA – EA, UN 2021) and its application for the Netherlands (Statistics Netherlands and WUR 2022), we noticed certain shortcomings that may require the SEEA EA (UN 2021) to be revisited. We focus on its application in the Netherlands as to date very few other applications of the SEEA-EA methodology have been published in peer-reviewed journals.

Our main concern with the existing frameworks is an observed bias towards economically important resources that can be easily monetized, which compromises the main objective of this exercise, namely sustainable management of ecosystems and ecosystem restoration.

The Situation

Since 2015, Statistics Netherlands (CBS) and Wageningen University and Research (WUR) have been working on the development of natural capital accounting for the Netherlands, following the conceptual guidance of the SEEA – EA (UN 2021). The technical report of this exercise was recently published (Statistics Netherlands and WUR 2022). While the methodology used represents a great start of a highly complex process, it still has room for improvement and requires some refinement. Further, it could be simplified to make it accessible and practically feasible to do these accounts for data-poor countries.

The ecosystem accounting exercise for the Netherlands was done by a large team of professionals in a data-rich environment, but it still took seven years from start to finish. To do a similar exercise for a country that lacks sound data may be near impossible to accomplish. Furthermore, the exercise in the Netherlands concluded that ecosystem services contributed a mere 1.9% to GDP. This was partly due to a negative trade balance regarding agricultural and timber produce (using the ecosystem services in exporting countries), but primarily due to a lack of accounting for services that cannot be easily translated into monetary values. A broad interpretation of the results suggests that if all the intact ecosystems in the country disappeared overnight, the economy would hardly be affected and life would continue as if nothing happened, seemingly only at the expense of ecosystem services in other countries. Moreover, the results showed that the value of protected areas in the Netherlands would actually increase with the construction of housing. It appears that the methodology applied primarily focussed on economic value, with a strong bias towards economically important resources – that is those that can be easily monetized.

As it stands, we noticed the following shortcomings that require urgent attention to prevent some in the financial sector from hijacking this exercise:

- Problems of a statistical nature.
- A lack of accounting for ecosystem complexities such as integrity, variability, synergies and externalities.
- Too much focus on the economic value of resources that can be easily monetized, thereby underestimating the actual value of nature (ecosystem services), with significant economic bias; thereby undermining the purpose of this exercise, namely sustainable ecosystem management.
- Difficulty in repeating the exercise in its current format in data-poor countries, due to the complexity of the system and the human-hours required.
- A lack of guidance in using the outcome in real life.

A few of these shortcomings were discussed in Turnhout et al. (2019), Vira et al. (2020) and a recent United Nations Environment Programme (UNEP) report (2022), but with a focus on the European Union-funded NCAVES (Natural Capital Accounting and Valuation of Ecosystem Services) and the Norwegian Agency for Development Cooperation-funded ANCA (Advancing Natural Capital Accounting) projects.

Accounting Problems

Statistical framework

The statistical method for all ecosystem accounting frameworks uses the Net Present Value (NPV) formula, which is the present value of future cash flows compared with the initial investments – that is to derive the present value of a cash flow we need to discount it at a particular rate, the discount rate (Statistics Netherlands and WUR 2022).

The Netherlands framework used the following simple NPV formula to estimate the value of a particular ecosystem service:

$$K_0 = \Sigma_{(t = 1;\, T)}\, d_t/(1 + r)^2$$

Where: d_t is the flow of income in year t, at a discount rate r, and an asset life T.

In simple terms, the discount rate (r) reflects the time value of money, which means that money available today is worth more than the same amount of money available in the future. The discount rate includes inflation, risk, and opportunity cost of capital. By applying the discount rate to future cash flows, the NPV formula calculates the present value of the cash flows, which is then compared to the initial investment to determine whether the investment is profitable or not.

When doing the capital accounting exercise for the Netherlands, the team used two assumptions: the flow of income for each ecosystem service is constant and equals the most recent cash flow, and the discount rate is kept constant at either 3% or 2% (Statistics Netherlands and WUR 2022).

Although the above formula is a correct expression of the present value of a cash flow stream, it can only be applied when both cash flows and discount rates are constants over time. This may be the case with single distinct resources such as minerals, energy or timber, but not for complex ecosystems that are highly variable, especially under conditions of climate change. Moreover, while a linear approach to single distinct resources may be defensible, it is definitely not defensible when applying it to highly non-linear interacting ecosystem services. Ecosystems are complex, with interconnected systems, where changes in one component can have non-linear effects on other components. These non-linear dynamics are not explicitly accounted for in the NPV formula, which assumes a linear relationship between inputs and outputs.

Because the focus of this exercise should be valuing and accounting for ecosystem services, where neither cash flows nor discount rates are constants over time, a more complex formula is required to avoid significant bias towards resources that are considered economically important.

The NPV formula used in the SEEA – EA (UN 2021) considers the annual expected ecosystem service value (ES_t) for each year in the future time period and discounts these values back to their present value using a discount rate (r_j), which may vary over time. The sum of these discounted values for all years in the future time period is the present value of the expected future ecosystem services. The formula also considers the potential for changes in the ecosystem over time represented by the expected changes in the amount of ecosystem services provided (EA_t) over time. These changes may be positive or negative and are also discounted back to their present value using the discount rate. Because this formula accounts for variable cash flows and discount rates, it is more suitable for use in valuing ecosystem services than the simple NPV formula used by the team in the Netherlands. We are, however, still using a linear approach to often non-linear complex and interacting ecosystem services.

If we continue with the approach in use, it will need further fine-tuning to account for ecosystem complexities such as integrity, variability, synergies and externalities, while the sum of all ecosystem services should always be range bound. The sum of all ecosystem services can never be zero or even small, because humankind would not survive without them. Also, with an ever-increasing world population and a changing climate, the sum of all ecosystem services can never be infinite, because it is not realistic to consider any service sustainable over prolonged periods. This implies that the total value of ecosystem services per unit time and for any spatial unit should always be range bound ($VT(EA) > 0$ and $< \infty$).

Although the NPV equation with variable cash flows and discount rates is a better approach to valuing ecosystem services than the one used by the Netherlands team, it still requires fine-tuning to ensure it also accounts for ecosystem complexities as well as 'existence values' that may be summarized as a set of ethical, aesthetic and spiritual values (Chan et al. 2016; Saner and Bordt 2016; Bordt and Saner 2018).

Ecosystem complexities

As mentioned above, a problem with these frameworks is that this approach can lead to an oversimplification of the complexity of ecosystems and their functioning, and thereby not accurately reflect their true value. Ecosystems are made up of a diverse array of plant, fungi and animal species – biodiversity – and ecological interactions between abiotic and biotic characteristics that cannot be easily reduced to a single monetary value. Although the economic value of certain species can be estimated, such as pollination by bees (Maes et al. 2021), carbon sequestration by elephants and great whales (Pershing et al. 2010; Chami et al. 2020; Berzaghi et al. 2022), and timber for certain commercially important tree species, they are merely cogs in highly complex systems, where everything is interconnected. Simply said, all the ecosystem components are required for economically valuable species and processes to survive and persist respectively. Thus, all species and processes have value. Not incorporating this in the framework will lead to an inadequate understanding of the true value of nature and will lead to a monetary value lower than it should be.

Once the value for each ecosystem service has been determined, all of them are enumerated to provide the total net worth of services provided by the system under study in period T (see above). However, even when system integrity and variability are accounted for as described below, there are still other problems that need to be addressed:

Accounting for ecosystem integrity

The integrity or health of an ecosystem determines what type and level of ecosystem services it can provide. Degraded, fragmented and/or polluted ecosystems frequently have poor species diversity and a lower capacity to deliver certain ecosystem services. Thus, the integrity of an ecosystem is an important parameter that should be included when valuing its services.

Ecosystem integrity can be measured by selecting a set of indicators that describe the current condition of an ecosystem and its changes over time. Examples include fragmentation due to land conversion, occupancy rates of key wildlife species, wildlife species diversity, presence or absence of certain insect species, abundance of tree or vegetation cover and plant species diversity, soil and water levels of nitrogen and phosphorus and other contaminants, the oxygen concentration in water, or the amount of soil organic carbon. The values of these indicators provide a snapshot of the condition of an ecosystem, and thus the potential to deliver ecosystem services as well as the costs of restoring degraded or polluted ecosystems.

To incorporate ecosystem integrity in the NPV formula, a term that reflects system health by using an index is required. The index should include a selection of key indicators that together provide a snapshot of the health of the ecosystem under study, or the reduction in the potential to deliver specific ecosystem services As an example, we may compare this with a composite index in finance, a statistical tool that groups together many different equities, securities, or indexes in order to create a representation of overall market or sector performance. Typically, the elements of a composite index are combined in a standardized way so that large amounts of data can be presented easily.

Each type of ecosystem may require a different set of indicators. As an example, for small forest areas in the temperate zone, surrounded by agriculture and livestock, nitrogen and phosphorus levels, levels of pesticides and other widely spread soil and water contaminants should be included, whereas a large savanna system in the arid tropical zone will require a completely different set of indicators, but should always include rainfall and temporal and spatial changes therein.

Ecosystem variability

The statistical framework does not consider the temporal and spatial variability of ecosystems, especially with a rapidly changing climate, resulting in a static picture of the systems under study. This problem may, however, be partly remedied by using an index that accounts for ecosystem integrity, updated at regular intervals.

Accounting for synergies

Ecosystem services often have positive interactions and dependencies, known as "synergies", which can enhance their overall value (Raudsepp-Hearne et al. 2010). For example, consider a natural tropical forest that provides a range of ecosystem services, such as water catchment and purification, provision of food, pollination, recreation, carbon sequestration and habitat for elephants and other wildlife. The value of these services may be greater when they are provided together in the same area, rather than if they were provided separately in different locations. This is because these services may interact in ways that enhance their overall value, such as by supporting biodiversity (elephants as landscape architects provide suitable habitat for other wildlife species) or by providing other benefits (high tourism revenue due to the presence of charismatic species such as elephants), increased carbon sequestration (due to the presence of elephants). To incorporate synergies between ecosystem services, we can add a term when enumerating all services for a particular system to represent the combined value of the interacting ecosystem services. This can be done by estimating the joint value of the interacting ecosystem services, which may be greater than the sum of the individual services.

Externalities

The total value of all ecosystem services may be greater than the sum of their individual values, not only because of synergies, but also due to the presence of "externalities", which are costs or benefits that are not reflected in market prices (UN 2019). For example, if an ecosystem service provides benefits to people who do not pay for it, such as clean air, this may not be reflected in market prices, but it still has value (UN 2019). For human beings and animals, the important component of air is oxygen, roughly 50% produced by primarily oceanic phytoplankton and the remainder through photosynthesis by terrestrial trees and other green plants. Air is invisible and does not carry a price tag, and as a result is used and abused, and polluted with impunity. Hence, in many places of our planet air quality is a problem. The UN 2030 Agenda establishes clean air as an integral element of sustainable development and sets out a much-needed complementary pathway for tackling atmospheric pollution at the global scale. Air pollution is a transboundary problem, as well as a local one. Improving air quality can often only be accomplished when collaborating at an international level, but it comes at a great cost, possibly resulting in a net negative entry for many ecosystem services accounts. A similar logic applies to freshwater bodies, in ample supply in some countries, but a rare and precious commodity in others. Where it is in ample supply it is frequently polluted, involving massive costs to improve water quality. However, when in low supply, climate change may exacerbate the situation. Cleaning up freshwater bodies and/or making water suitable for human consumption is expensive, resulting in yet another net negative entry for many ecosystem services accounts.

Economic bias

As mentioned above, the SEEA – EA (UN 2021) framework has too much focus on economic value and not enough on ecological value and integrity, which can lead to decisions that prioritize economic development over environmental protection – that is adequate investment in healthy ecosystems to promote sustainable management, and the restoration of degraded and/or polluted ecosystems. In a similar vein, the framework relies on monetary valuation of natural resources and ecosystems, which may be difficult and frequently subjective, and may lead to bias towards resources that are easily monetized, such as timber or minerals, while neglecting resources that are difficult or impossible to monetize, such as the diversity of animal, fungal and plant species (biodiversity) as well as cultural heritage and well-being. This can result in some resources being overvalued and others being undervalued, leading to bias and again to an inadequate accounting of the value of nature (ecosystem services).

Guidance

The UN ecosystem accounting framework (SEEA – EA, UN 2021) lacks a clear guidance on how to integrate the monetary values of ecosystem services into decision-making processes and policies. This makes it difficult for decision-makers to use the information provided by the framework to make informed decisions about ecosystem management – that is the management of habitats and landscapes. Moreover, the need for hard data, the complexity of the process and the amount of work involved may at some stage require the development of software, including data sets for similar situations and conditions, to make it easier for other countries to do these accounting exercises.

Non-human animals versus human beings

In addition to the argument that plant, fungal and animal species diversity is required for resilient ecosystems – that is sustainability for prolonged periods – ecosystems also need to be managed in keeping with diverse ethical, aesthetic and spiritual values, to consider the importance of nature beyond its economic values (Chan et al. 2016; Saner and Bordt 2016; Bordt and Saner 2018). This section will briefly discuss one of the many stumble blocks in valuing nature – that is putting a price tag on individual animal species.

Although ecosystem integrity or health and existence values are difficult to put a price tag on, some researchers managed to put a value on individual animal species. With the larger more charismatic animals one could for instance use income through tourism or revenues through hunting or safari licenses. In the case of elephants, as agents of climate change mitigation, carbon sequestration was used, resulting in a price tag of US$ 1.75 million for a live elephant over the course of its lifetime in a forest biome (Chami et al. 2020). However, is it correct to determine the current value of live elephants by their effect on carbon sequestration and therefore climate change alone? The intrinsic value of an elephant goes way beyond carbon, because as landscape architects, they impact biodiversity in terms of plant and animal life, hence the overall health and integrity of a particular ecosystem. Other less charismatic animal species, such as most insect species, many fish species, amphibians and reptiles, important parts of any ecosystem or biodiversity in general, are even more difficult to assign monetary value. In economic terms, exceptions are bees as pollinators for agricultural produce (Maes et al. 2021), and fish for human consumption. We should further ask ourselves whether it is morally and ethically just to reduce the intrinsic value of some species to a monetary value.

As humans, we tend to put everything in the context 'for humans', but bees for instance produce food for a vast array of animal species up to and including helping plants reproduce as part of their essential function of living in symbiosis. This simply implies that beyond their value for humans, they have unmeasurable value. Thus, it may be argued that non-human species and nature have inherent value and should be treated with respect and consideration, regardless of their usefulness to human beings. Here, we have partly entered the domain of ethical, aesthetic and spiritual values.

The question of whether non-human animals have the same rights as human beings is a complex and controversial topic that is subject to ongoing lively debate and discussion. From a legal perspective, animals are typically considered property and do not have the same rights as human beings. However, some countries and organizations have begun to recognize moral and ethical considerations and have implemented laws and regulations to give nature rights and to protect animals from abuse and neglect. As an example, in Ecuador, Articles 10 and 71–74 of the Constitution recognize the inalienable rights of ecosystems to exist and flourish, give people the authority to petition on the behalf of nature, and requires the government to remedy violations of these rights.

Box 1.

A recent study showed that all life on earth evolved from a single-celled organism that lived roughly 3.5 billion years ago, supporting the widely held "universal common ancestor" theory first proposed by Charles Darwin more than 150 years ago (Weiss et al. 2016). Embryology is important to understand a species' evolution, since some homologous structures can be seen only in embryo development. For example, all vertebrate embryos, from humans to chickens to fish, have a tail during early development, even if that tail does not appear in the fully developed organism. Moreover, both chick and human embryos go through a stage where they have slits and arches in their necks like the gill slits and gill arches of fish. These structures are not gills and do not develop into gills in chicks and humans, but the fact that they are so similar to gill structures in fish at this point in development supports the idea that chicks and humans share a common ancestor with fish. Given evolution and common ancestors we may expect a cognitive and emotional continuity between humans and other animals, such that other species also have something we can call morality. Morality requires two necessary conditions (de Waal 2006), empathy and reciprocity. In elephants, apes and dolphins we see sophisticated versions of these capacities in terms of targeted helping, altruism, consolation, cooperation and a sense of fairness.

Elephants for instance, are among the most intelligent of non-human animals. In terms of social intelligence, they are more advanced than every other animal except apes and some dolphin species. They live in families and those in turn in kinship groups that communicate over relatively long distances, and they have burial rituals and grieve their dead. Elephants appear to understand themselves as individuals, with thoughts that differ from the thoughts of other creatures. They suffer, and they understand suffering.

Moreover, recent research showed that elephants, like humans and bonobos, may be self-domesticated (Raviv et al. 2023). According to the human self-domestication hypothesis, humans evolved to be less aggressive and more cooperative. This unique set of traits may be the result of an evolutionary process of self-induced domestication. Since the most recent common ancestor of humans and elephants is likely the most recent common ancestor of all placental mammals, these findings have important implications for convergent evolution beyond the primate taxa (Raviv et al. 2023). Furthermore, although not yet certified by peer review, new research has suggested that wild African elephants address each other with individual specific calls – the equivalent of a name. This study presents the first evidence for vocal addressing of conspecifics without imitation of the receiver's calls in non-human animals (Pardo et al. 2023).

Some people argue that certain animal species have something we can call morality (see Box 1) and that non-human animals have the right to exist in the sense that they have the right to live out their natural lives without human interference, and that human beings have a moral responsibility to preserve the biodiversity of the planet and protect the habitats of other species. Others, however, argue that human beings are unique and have a special moral status that sets them apart from other animals, because they have the capacity for self-awareness, reason, and moral agency, which gives them a greater moral value and justifies different treatment.

Because non-human animals cannot distinguish between right and wrong, they have no rights, because they would not be able to respect those rights as it is beyond their comprehension. However, what is wrong and what is right varies across human cultures and is frequently adapted by those who are in charge. After all, morals are a set of guiding principles dating back to ancient Greece and ancient China, a long time ago, but they are rather recent in evolutionary terms.

However, as with most arguments, the truth lies somewhere in the middle, while we should also be practical and pragmatic about it. Therefore, assigning a monetary value to non-human species, either as an individual species or as part of an ecosystem integrity index, and nature in general, is a necessary step to make informed decisions about how to manage and protect these resources. Assigning a monetary value will help to raise awareness and understanding of the importance of preserving these resources for future generations and ensure that they are managed in a way that both serves our species by maximizing their economic value and by protecting the ecological integrity of entire systems that include all the non-human species and plant life. From this perspective, the discussion is primarily limited to assigning a monetary value to ecosystems and their components. With large species that have a tremendous impact on their environment, such as elephants on terrestrial landscapes and whales on marine environments (each great whale may sequester 33 tons of CO_2 on average (Pershing *et al.* 2010)), individual price tags under the carbon accounts may be warranted, but the value of most other non-human species as well as plant and fungal life, may have to be integrated in an index of the overall integrity of a particular system.

The Economics of Ecosystems and Biodiversity (TEEB) Approach

As an alternative framework, TEEB proposed a three-step approach to valuation of biodiversity and ecosystem services (www.teebweb.org):

1. **Recognising value** in ecosystems, landscapes, species and other aspects of biodiversity.
2. **Demonstrating value** in economic terms.
3. **Capturing value** involves the introduction of mechanisms that incorporate the values of biodiversity and ecosystems in decision making through incentives and price signals.

The general concern that financialising nature and its services will lead to commodification and marketisation is rebuked by TEEB. TEEB says they do not suggest placing blind faith in markets for price discovery of ecological commons. They say they offer a model for communication to decision makers in their own language, dominated by economics, as well as a toolkit for evaluating and integrating good stewardship in their decisions (www.teebweb.org).

Although the TEEB approach has advanced a significant effort to value ecosystems and biodiversity to integrate them into decision making, over the years, it has faced similar criticisms as the SEEA – EA (UN 2021) framework. These include:

- Monetisation and commodification of nature (Gómez-Baggethun and Ruiz-Pérez 2011; Sullivan 2013).
- Equity and justice concerns (Pascual et al. 2021).
- Simplification of complex ecosystem interactions (Spash 2015).
- Focus on market-based solutions (McAfee 2012).
- Questionable assumptions in valuation methods (Vatn 2009).
- Lack of empirical evidence for policy effectiveness (Chan et al. 2012).
- Potential for perverse incentives (Büscher and Fletcher 2015).
- Cultural and ethical limitations (Hirons et al. 2016).
- Dependence on data availability and quality (Costanza et al. 2014).

The Way Forward

While the SEEA – EA (UN 2021) has the potential to provide decision-makers with valuable information about the economic value of ecosystems and their components, it has several shortcomings that must be addressed. The need for hard data, the manpower and hours required to complete the exercise, the focus on economic value over ecological value and integrity, the reliance on monetary valuation, lack of temporal and spatial variability and the lack of clear guidance on the integration of the monetary values into decision-making processes and policies are some of the issues that must be addressed in order for the framework to be an effective tool for promoting sustainable management of ecosystems. This is especially important because the ultimate goal of this exercise is to mitigate climate change and to protect biodiversity, to maintain a liveable planet for future generations by focusing on the valuation and accounting for ecosystem services provided by nature capital.

Next to using variable cash flow and discount rates in a slightly more complex NPV formula than used for the exercise done for the Netherlands, the following shortcomings need to be remedied:

- ***Ecosystem integrity*:** It is near impossible to determine the monetary value of each and every species and process in a particular ecosystem. As such, it is better to index the overall health or integrity of an entire ecosystem, which should be closely correlated to spatial and temporal variability, to correct its actual monetary value, which includes all plant, fungal and animal species. Possibly, one of the existing indices or a combination of several may be used for this purpose. That is: occurrence and trends of target species as a proxy for ecosystem health and quality, thus integrity. For species that have a significant impact on climate change and the health of ecosystems, such as elephants and great whales, an exception should be made. However, the value of these keystone species should preferably come under the carbon stock accounts, in addition to the overall integrity index for ecosystems under study.

– ***Temporal and spatial variability of ecosystems*****:** This can be remedied by using a regularly updated index of ecosystem integrity, a proxy for ecosystem health and condition.
– ***Synergies*****:** The value of ecosystem services needs to account for synergies by adding a term when enumerating all services for a particular system to represent the combined value of the interacting ecosystem services.
– ***Externalities*****:** These should be avoided as much as is practically feasible, possibly by using proxies or approximations.
– ***Economic bias*****:** In a densely populated country with few 'natural' areas that are constantly modified by anthropogenic factors, it may be difficult to avoid some economic bias. However, in a relatively sparsely populated country with abundant natural resources, accounting for synergies and integrity may be sufficient to minimize economic bias.
– ***Ecosystem services range bound*****:** As mentioned above, the sum of all ecosystem services can never be zero or even small because humankind could not survive without them, while due to the increasing world population and a changing climate, the sum of all ecosystem services can never be infinite. This implies that the total value of ecosystem services per unit time and for any spatial unit should always be range bound ($0 < VT(EA) < \infty$). Perhaps the lower limit can in some way be associated with the Kunming-Montréal Global Biodiversity Framework, but the upper limit will be a spatial and temporal variable depending on ecosystem type and integrity. Moreover, as mentioned above, non-linearities can arise from ecological interactions. These non-linear dynamics are not explicitly accounted for in the NPV formula, which assumes a linear relationship between inputs and outputs.
– ***Data architecture, software development and guidance*****:** Once the system is in a state that it incorporates all the factors described above, with a sound balance between economic value and ecosystem value, software needs to be developed to make this exercise less complex and time consuming, using data sets for a wide array of ecosystems under varying conditions and interactive modules for entering recently acquired information (see Box 2). This should go hand in hand with the development of a manual for politicians and other decision makers on how to integrate the monetary values of ecosystem services into decision-making processes and policies.

Box 2.

Although we propose software solutions to break down the barriers of complexity and automate various time-consuming tasks, software sits atop a foundation of data. It is important to note that a more holistic approach can be taken to this data. An industry standard data exchange protocol for nature-based data sets should be developed adhering to the same methodologies we have seen in computer science, e.g., the Internet Engineering Task Force (IETF). Though some data sets are beginning to exhibit these qualities there is not an industry wide approach yet. By creating a standardization of data definition and enabling communication between software platforms via application programming interfaces (APIs) we accelerate data ingestion, systems integration and increase innovation. This reduces the complexity and time-consuming exercise of working with data sets. The new advances in Generative AI open the door to technologies to gain new insights and analysis to rich nature capital data sets – but this path to AI is paved with data that we must create in more efficient ways to share data across platforms as there will be no "Killer App" for nature capital or any conservation effort, it will take an ecosystem of partners exchanging data in a consistent manner to gain insights to make actions in our respective applications of that data. We see this already in industries like health care, with the adoption of the Health Level 7 (HL7) Fast Health Interoperability Resources (FHIR) standard. HL7 FHIR defines how healthcare information can be exchanged between different computer systems regardless of how it is stored on those systems.

Conclusion

Although the SEEA – EA (UN 2021) is an excellent start of a framework which, some time in future, may be very useful in translating the value of ecosystem services into monetary terms and integrating this into national accounts to create an enabling environment for conservation, our fear is that it is rapidly becoming too academic, too complicated, too time consuming and too easy to be controlled by some in the financial sector, to be of any practical use.

While the TEEB approach has proven useful in raising awareness of the economic value of biodiversity and ecosystems, it has also been criticised by many for similar shortcomings as the SEEA – EA (UN 2021) framework.

Sound maintenance of the remnants of often degraded and sometimes polluted bits of nature will not just depend on highly complicated bookkeeping systems that may take some more years to finalize and many years to implement, but does require urgent and collective action to reduce emissions and put a halt to ecosystem degradation, biodiversity loss and climate change – namely a collective change in attitudes and a complete revision of existing economic theories.

Moreover, the future of this planet does not depend on the often fragmented and degraded landscapes of the Global North, but by the large and still relatively intact landscapes of the Global South. Any system developed to promote conservation in the Global South and to make it easier for decision-makers to identify trade-offs and opportunities for cost-effective conservation using monetary valuation of ecosystem services needs to be holistic, easy to use and robust.

Having said this, it may be worth developing an alternative framework. For example, we could instead make a 180 degree turn, by simplifying and generalizing ecosystem classification for the semi-arid and moist tropical zones, and estimating the optimum monetary value of the collective services provided by each generic ecosystem – that is monetary aggregates for ecosystem services potential under ideal circumstances – to then establish status and monitor changes over time using proxies and key indices with the optimum situation as baseline.

In terms of restoration of degraded ecosystems and landscapes, the focus should be on the use of spatial planning tools to rehabilitate and connect dispersal areas and repair connectivity so that resilience of systems and species increases, and human-wildlife conflict is minimized.

Using this approach there may be no need to correct for ecosystem integrity, synergies, externalities and other complexities.

However, monetary evaluation estimates alone will never be sufficient for making decisions on optimal management of ecosystems – that is habitats and landscapes. Non-market services and elements of nature that are accepted as being essential to protect, whether species, processes or entire ecosystems, may require solutions that show both monetary and ecological results as a basis for robust management decisions.

As argued by Ralph Chami (pers. comm.), a new paradigm is required, because our current economic system values dead nature – that is a living nature has a price of zero. As a result it becomes invisible, so we can kill, cut, extract, pollute and abuse it with impunity. Because nature is our greatest ally in fighting climate change, its services should be valued, allowing these assets and services to be noticed (R. Chami, pers. comm.). Most unfortunately, time is not on our side and getting all things right and measured properly means witnessing the demise of nature and loss of its biodiversity. While the scientific community debates how to continue with the ecosystems accounting frameworks, the work on mitigating climate change and protecting biodiversity needs to proceed at a pace.

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