Accounting for Nature's Value

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Executive Summary

Economists see ecosystems as "natural capital," a productive asset that contributes to economic activity—and ultimately well-being—by providing "ecosystem services." This is akin to how machines and knowledge (produced capital and human capital, respectively) contribute to the production of goods and services of benefit to people, imbuing them with economic value that can be quantified. A forest, for example, provides timber that is used in construction, while also filtering the air we breathe, improving people's health and productivity. The forest's contribution is then embedded in the value of the products that use timber as well as in the health and economic impacts associated with cleaner air.

National accounts—which measure a country's aggregate economic activity, including Gross Domestic Product (GDP)—largely ignore natural capital and ecosystem services. This omission occurs because national accounts heavily rely on market transactions to identify and value economic activity, whereas ecosystems' contributions occur most commonly outside markets. This leads governments, businesses, and decisionmakers to ignore or misidentify some sources and uses of their income and wealth, skewing their decisionmaking.

Recognizing these shortcomings, many countries, including the United States, are increasingly moving towards Natural Capital Accounting (NCA), a system of measuring natural capital and ecosystem services in a way that allows for their integration with national accounts.

NCA will better represent connections between economic activity and nature in national accounts. Countries' and businesses' balance sheets will be more accurate, better reflecting nature's uses and value and ultimately leading to better decisionmaking. NCA also supports the construction of alternatives to GDP that economists have long been advocating for, such as Net Domestic Product (NDP), as they better represent changes in well-being and sustainability.

Presently, over 90 countries have begun to compile natural capital accounts. Generally, European countries are leading the way in this effort, but the United States is actively working to catch up to meet its ambitious goals, reflected in a recent national strategy to develop natural capital accounts. Over the first year of implementing this strategy, the United States has successfully published pilot accounts for land, water, air, and environmental activities, giving the country traction as a leader in NCA.

NCA's full potential will be realized when the accounts are comprehensive and regularly updated. Still in its early stages, NCA will face implementation challenges due to the difficulties inherent in measuring and valuing natural capital and ecosystem services as well as technical, institutional, and political constraints. These challenges include interpreting, communicating, and effectively utilizing the accounts for decisionmaking. Overcoming these challenges will require decisive efforts from statistical agencies, in partnership with researchers, non-governmental organizations, businesses, and the public. These efforts, which have been instrumental in advancing natural capital accounts in the past, will be key in their future development and use.

I. Introduction

Nature plays a fundamental role in sustaining economic activity and well-being, even in heavily industrialized nations like the United States. Pollinators, soils, and water sources support food production. Forests provide timber for construction, help prevent soil erosion and floods, and purify water. They also support biodiversity and clean the air, stabilizing the climate and improving people's health and productivity. Furthermore, natural landscapes provide spaces for recreation, enhancing people's physical and mental well-being and supporting tourist-related industries that create jobs. Measuring these linkages between nature and the economy is important for protecting and managing ecosystems and ensuring their ability to provide benefits to people in the future (Guerry et al., 2015; White House, 2023).

Recognizing nature's role in providing benefits that are valued by humans, economists (and increasingly policymakers) describe ecosystems as "natural capital," a kind of productive asset that contributes to the production of valuable goods and services by providing "ecosystem services." This framework, which has deep roots in environmental economics, values natural capital based on the value of the flow of its ecosystem services, in the same fundamental way that other forms of capital, such as machinery or buildings, are valued (Dasgupta, 2021; Guerry et al., 2015).

National accounts, which report countries' aggregate economic activity and calculate indicators like Gross Domestic Product (GDP), largely obscure the role of ecosystems in economic activity and the value of natural capital (White House, 2023). This oversight, long recognized by economists, occurs because national accounts largely rely on market transactions to record economic activity, whereas most of nature's contributions are public or common goods that are outside the scope of markets and, as such, go unrecorded. As a result, governments, businesses, and the public are left with incomplete and distorted estimates of economic activity, income, and the evolution of wealth, misguiding their decisionmaking (see **Box 1**) (Fleurbaey, 2009, p.1029; Nordhaus & Tobin, 1972, p.5; Stiglitz et al., 2009, p.22).

Recently, there has been a strong movement in the United States and abroad to develop "Natural Capital Accounting" (NCA), measures of natural capital and ecosystem services that can be integrated into national accounts (Bagstad et al., 2021; Hein, Bagstad, et al., 2020). This ongoing effort in the United States and abroad is substantial, and it is mobilizing government agencies, researchers, NGOs, and a broad array of actors (Bagstad et al., 2021; Hein, Bagstad, et al., 2020; Ingram et al., 2022). Globally, the United Nations' System of Environmental-Economic Accounts (SEEA), the internationally endorsed set of guidelines to collect environmental-economic data, constitutes a major movement in this direction. The SEEA complements the international framework for gathering economic data known as the System of National Accounts (SNA), and is shaping how countries, including the United States, undertake efforts to collect environmental-economic statistics (Hein, Bagstad, et al., 2020; United Nations et al., 2021). Currently, more than 90 countries have compiled natural capital accounts, with most in the pilot stage (United Nations Statistics Division, 2023).

While the United States currently lags behind many other developed nations in the compilation of natural capital accounts, it is rapidly catching up, as evidenced by the White House's recent publication of the "National Strategy to Develop Statistics for Environmental-Economic Decisions" (Bagstad et al., 2021; White House, 2024). This strategy, which runs parallel to other recent government initiatives seeking to incorporate environmental-economic information into decisionmaking, is an ambitious federal interagency initiative to develop a comprehensive set of natural capital accounts and indicators within the next 15 years. In its first year of implementation, this strategy has successfully guided the piloting of several natural capital accounts, including accounts for land, water, and air (OIRA, 2024; OMB, 2023; White House, 2023, 2024).

NCA has important potential applications. Just as data from national economic accounts are routinely integrated into public and private decisionmaking, natural capital accounts can likewise have a major influence on government, business, and public decisionmaking alike. For example, NCA can inform businesses' portfolio investments, by providing a structured source of information on their dependencies on natural assets. Governments can find applications for NCA in the design, implementation, and evaluation of a wide range of policies, including, but not limited to, environmental and energy policy (Ingram et al., 2022; Ruijs et al., 2019).

In this report, we provide an overview of NCA for non-economists. We primarily focus on the United States' effort to integrate natural capital into national accounts, though we place it in the greater context of similar global efforts and the UN's SEEA. In doing so, we discuss some of the factors that motivate this endeavor, describe the conceptual underpinnings of NCA, highlight some of its potential uses, and document current efforts to develop natural capital accounts. In our concluding section, we discuss challenges to their implementation as well as areas for future research.

Box 1 - Key Economic Concepts

National Accounts measure a country's production and how the income resulting from that production is used for consumption, savings, and the accumulation of capital assets by different sectors of the economy (United Nations et al., 2009, par. 1.27-1.33). These, and other related and often-misunderstood terms, are defined below.

Capital refers to productive assets used in the production of goods and services. It includes financial and non-financial assets. Economists have paid particular attention to three forms of **non-financial capital**: manufactured (or produced), human, and, more recently, natural capital (see **Figure 2**) (Dasgupta, 2021, p. 38; Guerry et al., 2015, p. 7349; OECD, 2008, p. 206).[1]

- **Manufactured (or Produced) Capital** is defined as the material assets built by humans, such as roads, buildings, machines, or ports.
- **Human Capital** refers to the knowledge, skills, competencies, and attributes embodied in people.
- **Natural Capital** is defined as the components of ecosystems, excluding humans and their contributions to production, that help generate goods and services from which humans derive benefits.

Income in economics goes beyond the common understanding of the term as the money earned by a person (or a country) (Oxford English Dictionary, 2024). Two key interpretations exist. Firstly, Fisherian income, the prevalent view, refers to income as the services ultimately enjoyed by people. This definition emphasizes the "inflows" and aligns closely with the common usage of the term. Secondly, Hicksian income subtracts from the inflows the depreciation and consumption of capital assets resulting from the production processes (e.g., cutting down a forest to produce timber, or the wear and tear of a machine due to its use). Hicksian income corresponds to the maximum amount that a person (or a country) can consume without reducing the value of the stock of assets and is, in this sense, a measure of "sustainable income" (see below) (Lawn, 2006; Mates, 2004; Sefton & Weale, 2006).

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[1] There are other types of assets that economists have been more reticent to classify as "capital" because they are less measurable, but that fit the general definition of being non-financial productive assets. For example, "social capital" is often used to refer to factors like mutual trust and solidarity, but it is not included in quantification exercises of the value of capital and wealth (Dasgupta, 2021, p. 38).

Wealth is the value of all assets that contribute to the production of goods and services that generate income and support human well-being (K. J. Arrow et al., 2012; World Bank, 2021, p. xxix).[2]

Sustainability is a consumption path that allows every future generation the option of being as well-off as its predecessors. It then corresponds to a consumption path in which wealth does not decrease (K. J. Arrow et al., 2012; Sefton & Weale, 2006; Solow, 1993).

Gross Domestic Product (GDP) is the value of final goods and services produced within a country's borders over a specific time period (typically a year). Because all production is either consumed, saved, or exported, and is a source of income and surplus, GDP can be defined and derived in three ways (see **Figure 1**) (United Nations et al., 2009, para. 16.47 & 16.48):[3]

1. As the value of output minus the value of goods and services used as inputs in production.
2. As the sum of expenditures on final consumption, savings (gross capital formation), and exports minus imports (net exports).
3. The sum of wages (income payments), including profits (surpluses).

Net Domestic Product (NDP) is GDP minus the consumption of capital assets. It corresponds to a measure of Hicksian income and is a better approximation of changes in wealth and sustainability than GDP because it considers changes in capital that GDP ignores (Mates, 2004, p. 1; United Nations et al., 2009, para. 16.52).

[2] This definition of wealth is more closely tied to Fisherian income but is still meaningful if we consider it refers to Hicksian income. See Lawn (2006) and Mates (2004) for a discussion. The White House's national strategy discussed above uses Fisherian income as a guiding concept (White House, 2023, p. 27).

[3] For simplification, we abstract from taxes and subsidies, some of which need to be taken into account in GDP calculations.

II. National Accounts, Their Uses, and Their Limitations

National accounts significantly influence how governments, businesses, and households understand the economy and make decisions (United Nations et al., 2009, para. 1.1). The accounts measure aggregate economic activity and are the basis for the calculation of key indicators, such as GDP—the most popular indicator of an economy's overall health. Despite their wide use, however, national accounts have important limitations in measuring the relationship between economic activity and nature. In this section, we provide an overview of national accounts, their uses, and their limitations.

National Accounts and the System of National Accounts

Since the 1950s, countries (including the United States) have followed the System of National Accounts (SNA), a common set of guidelines emanating from the UN's Statistical Commission, to compile their national accounts. These guidelines promote data consistency, reliability, and comparability across countries and time.

Broadly, the SNA defines methods to measure a country's production of goods and services, and how the income generated by production is used for consumption and the accumulation of assets. These flows and stocks are registered in a set of connected accounts, graphically represented in **Figure 1**. These accounts measure transactions of goods and services between different economic units (e.g., households, government, and corporations) in monetary terms, relying largely on market transactions to identify and register information. **Box 2** provides further details.

Supply-use tables (SUTs) are important products of national accounts. They register the supply and use of goods and services both in final consumption and as intermediate inputs to production. SUTs illustrate how GDP can be calculated from the difference between the value of final and intermediate goods and, how value is added along the production chain until final consumption. **Table 1** illustrates a stylized example.

Figure 1 - Set of Connected Accounts in the SNA, a Simplified Representation

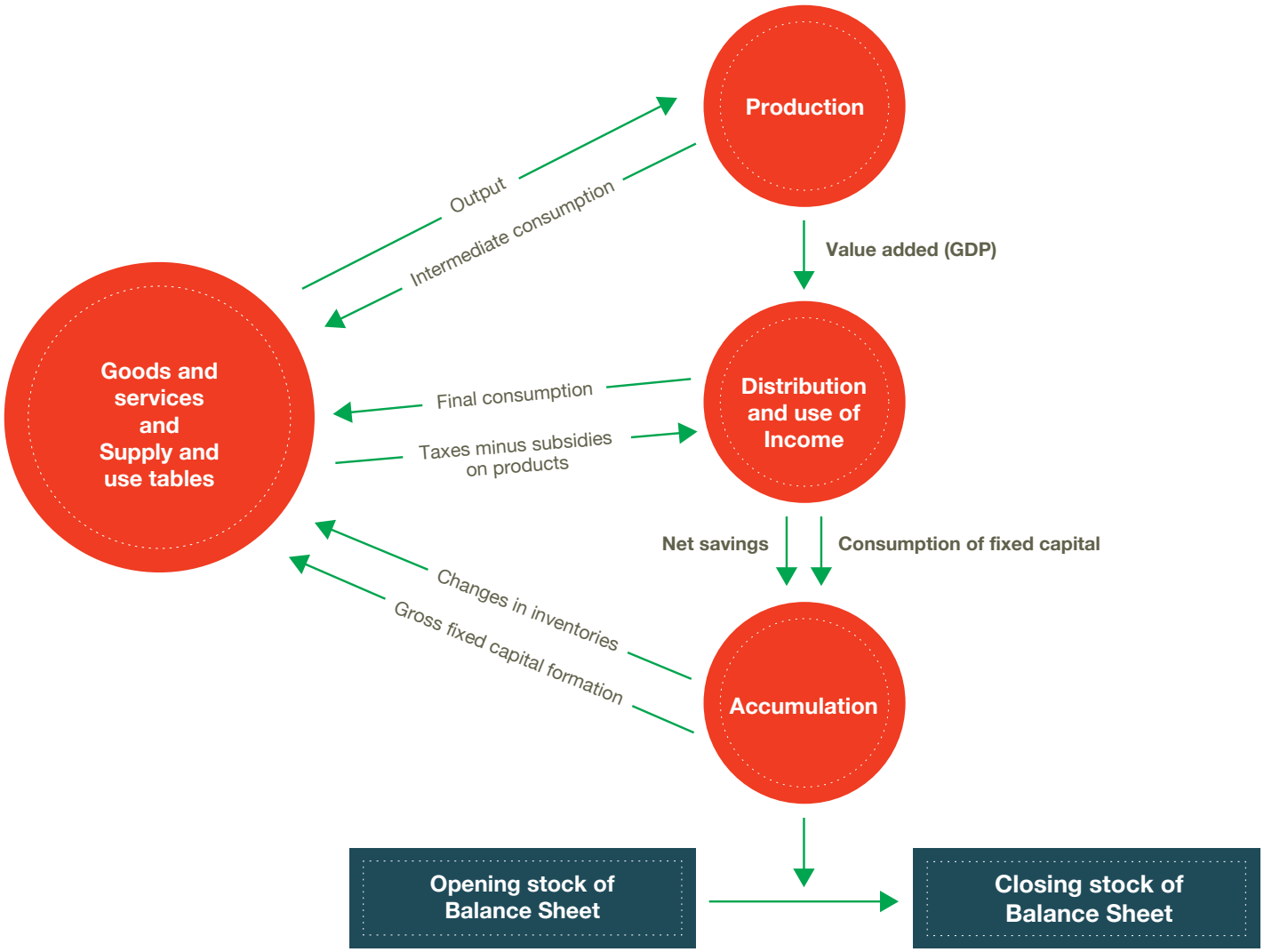

Figure 1 shows a simplified diagram (e.g., closed economy and no financial assets) of the main set of accounts in the SNA. All accounts register production, consumption, and income from transactions of goods and services between institutional sectors (e.g., government, businesses, households) in monetary terms. **Production** accounts measure production and the generation of income. **Distribution and use of income** accounts show how income is distributed among different sectors. **Accumulation** accounts register transactions that affect the changes in the value of the stock of assets. **Balance Sheet** accounts show the value of stocks of assets and liabilities. Arrows correspond to the entries that change the value in the accounts and the direction of the flows. Source: own elaboration based on United Nations et al. (2009, para. 1.16-1.25).

Table 1 - Supply-Use Tables, a Stylized Example (in Monetary Units)

	Forest industry	Manufacturing industry	Household final demand	Total
Supply				
Logged timber	50			50
Furniture		80		80
Use				
Logged timber		50		50
Furniture			80	80
Value added (supply minus use)	50	30		80

Table 1 provides a stylized example of a supply-use table, an important product of national accounts. Supply-use tables register the use of final goods and services for consumption as well as their use as inputs in the production of other goods and services. This method allows one to calculate the value added by different sectors along the production chain, until final consumption. This table shows a stylized example of how national accounts register the way timber is produced and used as an intermediate good in furniture manufacturing, which is a final good demanded by households. The upper section shows the value of logged timber (50) and furniture (80) supplied by the forest industry and the manufacturing industry, respectively. The lower section shows the value of logged timber and furniture used by the manufacturing industry (50) and households (80). Value added is the value of supply minus the value of use. In the example, the value added of the manufacturing industry is 30, the value at which it sells to households (80) minus the price at which they buy timber from the forest industry (50). Source: adapted from United Nations et al. (2021, p. 254).

Box 2 - National Accounts in the United States and Abroad

National accounts measure a country's production of goods and services, how income is generated by production, and the use of this income for consumption or savings, as well as its distribution among different sectors in the economy. In addition, national accounts measure a country's balance sheet, which is the value of the stock of manufactured and financial assets. Since the 1950s, countries compile their national accounts according to **the System of National Accounts (SNA),** the internationally agreed-upon set of guidelines from the UN's Statistical Commission (BEA, p.3-4; SNA 2008, par 1.6).

To identify and register economic activity, national accounts define a set of **"institutional sectors"** (namely households, corporations, and the government) and record the production and consumption activities based on transactions between units belonging to each sector in a set of **connected accounts** (see **Figure 1**). National accounts include **supply-use tables (SUTs)**, which are accounts that register the use of goods and services for final consumption and investment, as well as their use as inputs in the production of other goods and services. SUTs illustrate how value is added by different sectors and how the income generated in production is distributed among them (see **Table 1**). National accounts also include satellite accounts, which are accounts that are compiled to bring attention to a particular sector or activity. For example, there are **satellite accounts** for education, tourism, and environmental protection activities (United Nations et al., 2009, para. 29.4).

Transactions are recorded in monetary terms based, mostly, on the **"exchange value"** concept, which refers to the value at which goods, services, and assets are, or could be, traded in markets. As such, market transactions are automatically included in the accounts at their market prices. When market prices are not directly observable, the SNA uses prices in similar items, with some adjustments for quality and other differences. When there are no markets from which to extract relevant prices, goods and services are sometimes valued at their cost of provision (United Nations et al., 2009, para. 3.118-3.135).

The National Income and Production Accounts (NIPAs) are the set of accounts in the United States that collect economic data consistent with the SNA guidelines (Bagstad et al., 2021). The Bureau of Economic Analysis (BEA) prepares NIPAs using data from a variety of sources. Data from government agencies form the backbone of these accounts and are complemented with data from trade associations, businesses, international organizations, and other sources (BEA, 2023, p. 1). NIPAs are organized differently than the SNA structure outlined above but convey largely the same information. There are, however, some minor differences. For instance, NIPAs use a more intricate classification for economic sectors, do not include estimates for illegal production, and categorize certain goods as investment that are labeled as consumption in the SNA (e.g., investment in defense weapons systems) (Mead et al., 2004).

Uses of National Accounts

National accounts compile information used to analyze and evaluate the performance of the aggregate economy (United Nations et al., 2009, par. 1.27). They provide consistent and systematic measurements of an economy, which is important for decisionmaking because it allows for comparisons of economic performance across time and across countries.[4] Monetary valuations, an essential component of the accounts, allow for comparisons of different activities based on a common monetary metric, which is necessary for the calculation of aggregate statistics and the evaluation of tradeoffs in economic analysis. For example, a monetary valuation allows policymakers and the public to compare a country's food production with its production of medical services despite their very different nature, and add up their value to calculate indicators such as GDP (Stiglitz et al., 2009, p.21).

National accounts and the indicators derived from them are widely used by a variety of actors (Ruijs et al., 2019; United Nations et al., 2009, para. 1.27-1.35). Government agencies, analysts, researchers, and others use national accounts to design, implement, and assess the effects of economic policies. For instance, they provide key inputs to governments' budgets and tax projections, which influence government spending, as well as to central banks' monetary policy decisions (BEA, 2023, Chapter 3; United Nations et al., 2009, para. 1.3). Businesses use national accounts to monitor the general economy, specific industries, and individual sectors, and to make forecasts that are essential for their investment and strategic decisions (United Nations et al., 2009, para. 1.32). For example, businesses forecast future sales based on expected GDP growth to decide whether to enter a new market or make new investments. Similarly, individuals use indicators from national accounts to form expectations about the economy that guide their decisions, such as buying a home or searching for a new job. The public also uses these accounts—especially summary indicators like GDP—as a benchmark to hold policymakers accountable (BEA, 2023, Chapter 1; Coibion et al., 2018; United Nations et al., 2009, para. 1.33; Van den Bergh, 2009).

Limitations of National Accounts

Economists and experts have acknowledged the limitations of national accounts since their inception. One major limitation, often the focus of great attention, results from the fact that the accounts mainly record activities and assets based on market transactions, which leads them to exclude many assets and transactions that benefit society but fall outside the market's scope. Three commonly cited examples are the accounts' treatment of non-paid household work, natural resources, and externalities (Fleurbaey, 2009; Nordhaus & Kokkelenberg, 1999; Nordhaus & Tobin, 1972; Stiglitz et al., 2009, pp. 22 & 23; United Nations et al., 2009, para. 1.46).

Unpaid household work, such as caregiving for the sick, educating children, or meal preparation, remains unaccounted for because there are no recorded transactions. In contrast, these services are included when contracted to others in the market. Consequently, the former case does not contribute to GDP while the latter does, even though economic activity remains essentially the same in both situations (United Nations et al., 2009, para. 1.41).[5]

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[4] The main purpose of national accounts is to compile information about a country's aggregate economy. Their structure, however, allows countries to compile information at different levels of aggregation. In the United States, for example, GDP estimates are available at the national, state, and county levels.

[5] While national accounts do provide guidelines for imputing the value of certain economic activities in the absence of market transactions, data and conceptual limitations make these the applications inconsistent (Stiglitz et al., 2009). For instance, the accounts typically impute the value of goods produced within the same household, such as fuel or food, but do not impute the value of services, such as caregiving for a family member. A notable exception is the imputation of rental income from owner-occupied dwellings (United Nations et al., 2009, para. 6.22-6.34).

National accounts include natural assets and their value if they, or the goods that they provide, are owned and traded (or potentially traded) in markets. But because many of the benefits that humans derive from nature do not involve market transactions, these are often excluded from national accounts. For example, the accounts register forest-derived timber sold in markets, but they omit the forest's contribution to people's health through improvements in air quality and the benefits people derive from visiting it for recreation (unless the forest's owners or managers charge a fee for access). Note that the forest may also regulate the local climate, prevent erosion, and provide habitat for animals that control pests, all of which are activities that may increase yields in nearby agricultural fields. While national accounts will capture these yield increases in crops' market value, they will not attribute them to the forest, which provides uncompensated benefits.[6] Instead, these yield increases will be attributed to other forms of capital, such as manufactured or human capital (Fleurbaey, 2009; Heal, 2020).[7]

These omissions distort the estimates of both the level and the sources of a country's income and wealth, leading to misguided decisionmaking. For example, policymakers may neglect the non-market benefits that forests provide to agricultural production or recreation, as their value is not explicitly included in national accounts. Consequently, when calculating a country's balance sheet, natural (and total) assets will be undervalued. Relatedly, while businesses may internalize some of their dependencies on natural assets affecting their operations, they lack solid and standardized information to evaluate these dependencies. As a result, they may wrongfully evaluate risks and opportunities, resulting in poor decisions that negatively impact their competitiveness (White House, 2023, p. 3). **Box 3** provides some examples of national accounts' limitations.

Box 3 - Examples of National Accounts' Limited Treatment of Nature

National accounts include natural assets and their contribution to economic activity if they are owned by recognized institutional units (including the government) and thus are—or could be—traded in markets (United Nations et al., 2009, para. 1.47). Since many natural assets and the benefits that they provide to people are not subject to ownership rights or traded in the marketplace, the accounts exclude them. This exclusion results in understating the value of natural assets and misattributing their benefits to other forms of capital and is an important reason why changes to GDP are an inadequate measure of changes in well-being. This box describes some examples of national accounts' limited treatment of nature.

Production by natural assets is unaccounted for if they are not owned. For example, the natural growth of fisheries in the high seas is not counted as production in national accounts because they are not subject to ownership rights and are not traded in markets. On the other hand, the growth of fish stocks on fish farms is included in the accounts. Similarly, the growth of wild, uncultivated forests is excluded, but the cultivation of trees that can be used for timber or other uses is included as production in national accounts (United Nations et al., 2009, p. 1.43).

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[6] Externalities are benefits (positive externalities) and costs (negative externalities) imposed by one economic unit on another that are not compensated. National accounts do not record uncompensated transactions, and thus, even if the consequences of an externality (e.g., yield increases) are recorded, they cannot attribute the externalities to the units that generate them.

[7] Some estimates suggest that these omissions and misattributions are large. The World Bank, for example, provides some estimates where the value of natural capital is similar to manufactured capital in some countries (World Bank, 2021, p. 71). We provide an illustration of how national accounts misattribute nature's contributions in Table 2.

National accounts record the **depletion of natural resources** as a loss in asset value if the assets are owned. In contrast, the loss of public goods that are not owned is not included. For example, water stored in a private aquifer is accounted for, and so is the aquifer's depletion, which will be considered when calculating its value as an asset. In contrast, groundwater aquifers, which are not owned, are not registered and their depletion goes unaccounted for in the accounts (Fenichel et al., 2016). This omission can create a misleading result in that GDP rises as natural, and perhaps total, wealth declines. For example, while using all water in an aquifer contributes $100 to agricultural production (and thus to GDP) today, its exhaustion means that water will not be available next year. So, GDP increases today by $100, but wealth declines by the value of future agriculture production losses, which are not registered in the accounts.

Defensive expenditures are expenditures incurred to avoid negative outcomes. They often involve expenditures that replace or enhance natural assets. National accounts record expenditures, rather than the physical, biological, or social outcomes of defensive expenditures (White House, 2023, p. 23). For example, if investing $40 in an urban forest results in $60 of medical cost savings due to reduced heat stress, national accounts will register a $20 reduction in GDP (a decrease of $60 in medical expenditures, and an increase of $40 from the expenditures in the urban forest). This result illustrates that GDP may fall even though investing in the forest results in cost savings, better health, wealth increases, and overall improvements in well-being.

National accounts wrongfully **attribute** the contributions of natural assets to other forms of capital. For example, property values likely internalize flood protection from coastal dunes, marshes, or wetlands, but these are not attributed to the relevant natural assets because there are no recorded transactions (Barbier, 2019; Taylor & Druckenmiller, 2022). Similarly, in the urban forest example described above, if the savings are spent elsewhere in the economy, the additional GDP is not attributed to improved health or the forest (White House, 2023, p. 23).

National accounts do not explicitly measure **environmental externalities** because, by definition, these are not compensated transactions. What's more, because externalities may affect economic activities that are measured to some extent in the accounts, they lead to misleading results. For example, while air pollution may decrease productivity (a fact which is unaccounted for in the accounts) and thus GDP, it may also increase GDP by increasing health expenditures. Relatedly, while pollution itself is not recorded, cleaning activities to remove air pollution will increase GDP if they involve hiring labor or machinery. Likewise, if a polluting firm pays a tax or a fine for their pollution, the accounts register it (United Nations et al., 2009, para. 1.81).

III. Natural Capital, Ecosystem Services, and Natural Capital Accounting

Treating nature as a form of capital is at the heart of current efforts to incorporate environmental-economic information into national accounts. This approach, deeply rooted in environmental economics, recognizes ecosystems as productive assets that can be valued based on the benefits they provide to people (K. J. Arrow et al., 2012; Chaplin-Kramer et al., 2019; Costanza et al., 1997, 2014, 2017; Farber et al., 2002; Guerry et al., 2015; Heal, 2007).

More precisely, this framework defines **natural capital** as the components of ecosystems, excluding humans and their contributions to production, that help generate goods and services that are of value to people. In turn, those contributions by natural capital to the production of valued goods and services are defined as **ecosystem services** (Guerry et al., 2015, p. 7349; OIRA, 2024; United Nations et al., 2021, para. 6.9). For example, trees in a forest contribute to air filtration, improving people's health. The trees constitute natural capital, and their contribution to improved air quality is an ecosystem service. Ecosystem services refer to contributions to the production of goods and services that are directly used or consumed, as well as contributions to the production of goods and services that are used as inputs in the production of other goods and services. For example, the trees' contribution to air quality is directly consumed by humans, but trees also provide timber, which is used (and valued) as an input in construction and other industries. **Box 4** provides further examples.

A distinction is often made between "final" and "intermediate" ecosystem services. The former refers to services for which the user is an economic unit (e.g., a household or a business), and the latter refers to services that are used by another, or the same, ecosystem. This distinction can help analysts avoid capturing the same value more than once.[8] For instance, a forest may provide habitat for animals that control pests, benefiting people by increasing crop yields in nearby agricultural fields. This means that the forest's contribution to agriculture is included in the final value of crops. Then, if one adds the forest's value (inclusive of its contributions to agriculture) and the final value of crops, one would be counting the forest's contributions to agricultural production twice (Karp et al., 2018; OIRA, 2024, p. 35; United Nations et al., 2021, para. 6.24-6.30).

Natural capital and ecosystem services are intrinsically connected, but distinct, concepts. An important difference is that, while natural capital is a stock (a measure of quantity at a particular point in time), ecosystem services are flows (changes in quantity over time) that emanate from that stock. Economists conceptualize that people derive benefits from the flow of ecosystem services, not the stock of natural capital. Accordingly, the value of natural capital corresponds to the **present value** of the ecosystem services it provides over time.[9]

In this framework, natural capital is a component of wealth that is part of the economy's "productive base" alongside manufactured, human, and other forms of capital (Arrow et al., 2012, p.329; World Bank, 2021, p.429). Moreover, in many—if not all—cases, ecosystem services result from the interaction between natural and those other forms of capital. For example, the contribution of marine ecosystems to the provision of seafood (an ecosystem service) depends on fish

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[8] Counting the benefits more than once is generally known as "double-counting." Avoiding double-counting is an essential principle of proper accounting, fundamental to national accounts and natural capital accounting.

[9] The present value is the current value of future benefits. It involves projecting those benefits over time and then using a discount rate, which reflects that a dollar today is worth more than a dollar a year from now, to convert these future benefits to their current market value (i.e., society's current willingness to pay for this future benefit) (Caplin & Leahy, 2004).

stocks (natural capital), but also on fishers (human capital) and fishing vessels (manufactured capital) (United Nations et al., 2021, par. 6.3.2). The term ecosystem service precisely refers to the ecosystem's contribution to the benefits associated with this joint production.

In most cases, natural capital valuations cannot rely on direct market transactions, as ecosystem services are often non-rival, non-excludable, and not traded in the marketplace.[10] In this context, economists use multiple valuation techniques to infer the monetary value of a given ecosystem service. These methods rely on prices and actual or expected expenditures in similar or related markets, as well as surveys (Dasgupta, 2021b; Farber et al., 2002; Liu et al., 2010; OECD, 2018; United Nations et al., 2021, par. 9.3; OIRA, 2024, p.27). Some of these methods are described in **Box 5**.

Natural Capital Accounting (NCA), the focus of this report, is the process of measuring natural capital and the ecosystem services that it provides in a manner consistent with national accounts. More specifically, NCA expands national accounts by valuing the contributions of ecosystems to economic activity and integrating those values into existing national accounts (Bagstad et al., 2021; Hein, Bagstad, et al., 2020). **Figure 2** provides a simplified representation of how economists think about the different forms of productive assets, their relationship to important economic variables (e.g., production, consumption, income, savings, and benefits), what is included in national accounts and GDP, and how NCA expands the measurement of economic activity.[11]

NCA draws from a rich history of ecosystem services and natural capital valuation, incorporating established classifications and valuation methods from this tradition (Guerry et al., 2015; United Nations et al., 2021, par. 6.1-6.7).[12] However, NCA is distinct from more general natural capital valuation exercises, as it specifically aims to align with national economic accounts. For example, while some natural capital valuation exercises may use changes in consumer surplus or willingness to pay to monetize ecosystem services and natural capital, NCA exclusively adopts the exchange value concept for monetization, which is essential for its consistency with national accounts (Hein et al., 2020, p.514; United Nations et al., 2021, par. 1.67). Moreover, NCA does not account for non-use value (the value individuals put on goods and services even if they will not use them now or in the future), unlike other ecosystem valuation methodologies that do take it into account (OIRA, 2024, p. 10; OMB, 2023, p. 34; United Nations et al., 2021, para. 6.71).[13]

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[10] Non-rival means that the enjoyment of a good or service by one person does not prevent its enjoyment by someone else. Non-excludable means that nobody can be prevented from using or accessing the good or service.

[11] As a relatively new area of work, there is an evolving use of the terminology. For example, Ingram et al. (2024) distinguish between National Natural Capital Accounting (NNCA) and Corporate Natural Capital Accounting (CNCA) to refer to accounting efforts by countries and corporations, respectively. Corporations are increasingly developing accounting methods to include natural capital into their balance sheets, but these efforts are not necessarily consistent with national accounts. For the purpose of this report, we use NCA as implying consistency with national accounts, but we acknowledge this is not a stable definition.

[12] See, for example, The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005); The Economics of Ecosystems and Biodiversity initiative (UNEP, 2010), the Mapping and Assessment of Ecosystems and their Services (MAES) initiative (Maes et al., 2013); the Natural Capital Project at Stanford University (Sharp et al., 2014); the Integrated system for Natural Capital Accounting (INCA) project (Vallecillo et al., 2019); and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Díaz et al., 2015).

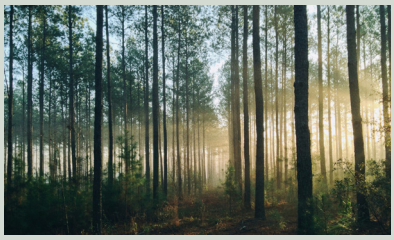
[13] The potential use of an ecosystem service in the future is accounted for in NCA, and natural capital valuations exercises in general, in the future flows of ecosystem services (United Nations et al., 2021, par. 6.71).

Box 4 - Key Concepts in Natural Capital Accounting

Natural capital is defined as the components of ecosystems, excluding humans and their contributions to production, that help generate goods and services from which humans derive benefits (Guerry et al., 2015, p. 7349).

Ecosystem services are the contributions of ecosystems to economic and other human activity and the benefits those contributions provide (Guerry et al., 2015, p.7349; OIRA, 2024, p.1; United Nations et al., 2021, par. 6.9).

A few examples include:



Forests (natural capital) contribute to air filtration, which improves health, and are a source of recreation for visitors (ecosystem services).

Sand dunes (natural capital) prevent coastal erosion, which preserves spaces for recreation (beaches) and protects property (ecosystem services).

Wetlands (natural capital) protect houses from flooding (ecosystem service).

Riparian forests (natural capital) prevent erosion and filter water, contributing to soil quality, increased crop yields, and the availability of safe drinking water (ecosystem services).

Soil (natural capital) contributes to the production of crops (ecosystem service).

Natural Capital Accounting (NCA) measures ecosystems and the ecosystem services they provide in a manner that allows them to be incorporated into national economic accounts (Bagstad et al., 2021, p.2).

Box 5 - Valuation Techniques for Ecosystem Services and Natural Capital

Many, if not most, ecosystem services are not traded in markets. In this context, economists rely on various techniques to infer their value. These methods are usually classified into two broad categories: "revealed preference" methods, which rely on behavior in other (related) existing markets, and "stated preference" methods, which use information from questionnaires. Economists typically prefer revealed preference methods, when available, because of the strictly hypothetical nature of stated preference methods. In this box we describe some examples of revealed preference methods to calculate the value of natural capital and ecosystem services (Dasgupta, 2021; Farber et al., 2002; Liu et al., 2010; OECD, 2018; OIRA, 2024, p. 27; United Nations et al., 2021, para. 9.3).

Changes in productivity. The value is inferred from changes in output derived from changes in the supply of the ecosystem service used in production. For example, the contribution of bats to agricultural yields (through their role as pest controls) has been measured by researchers through changes in yields in nearby agricultural fields that followed changes in bat populations (Frank, 2017; Manning & Ando, 2022; United Nations et al., 2021, par. 9.38).

Hedonic pricing. The value is inferred from differential property or rent values that result from differences in ecosystem characteristics. For example, in cities, property values are higher when they are closer to green areas. This differential is used to estimate the value people assign to the different amenities that these green areas provide, such as cooling during hot days or spaces for recreation (United Nations et al., 2021, par. 9.40-9.43).

Travel Costs. The value to visitors is extracted from the number of trips at different travel costs for different individuals. For example, the value of an open-access natural park that has no entrance fee is inferred from the number of visitors, their travel distances, and how much they spend to get to the park (United Nations et al., 2021, par. 9.47 & 9.48).

Residual values and resource rent. The value is estimated by taking the gross value of the final marketed good and deducting the cost of all other inputs (including labor, produced assets, and intermediate inputs). For example, the value of ecosystem services in agriculture may be calculated by deducting the cost of labor, fertilizer, and machinery from the price of the commodity (United Nations et al., 2021, par. 9.36 & 9.37).

Replacement costs. The value is estimated by the cost of replacing the ecosystem service with something that provides the same services. For example, the value of a forest's water filtration services is calculated using the avoided costs of a water treatment facility that would be needed if the ecosystem service didn't exist (United Nations et al., 2021, par. 9.50 & 9.51).

Value transfer (or benefit transfer). While not a valuation method in itself, value transfer is an important concept and method extensively used in ecosystem services valuation. It refers to using the estimates for the value of an ecosystem service made in one location to estimate the value of a similar ecosystem service in another location where there are no primary studies. It generally involves adjusting the estimates at the initial location based on characteristics of the new location, for example to account for different demographics that may influence the number of users of the ecosystem service (Meya et al., 2020; OIRA, 2024, p. 28; OMB, 2023, p. 37; United Nations et al., 2021, para. 9.75 & 9.90)

Figure 2 - The Economy, National Accounts, and NCA

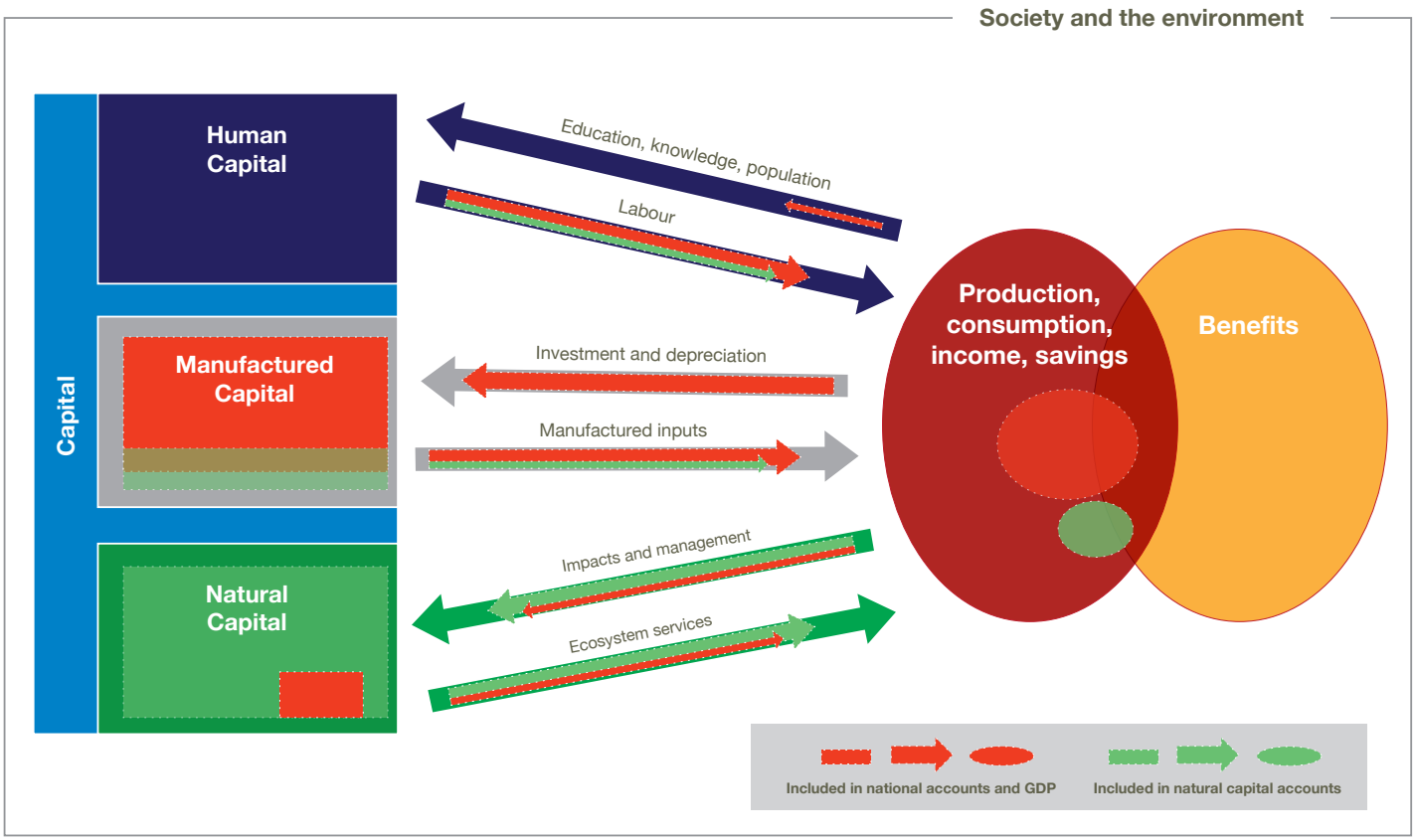


Figure 2 provides a simplified representation of how economists think about the different forms of productive assets, their relationship to important economic variables (e.g., production, consumption, income, savings, and benefits), what is included in national accounts and GDP, and how NCA expands the measurement of economic activity of national accounts to better reflect the interactions between the nature and the economy. In doing so, NCA helps identify more accurately the contributions of other forms of capital to the production of goods and services. Red circles, arrows, and squares denote what is measured in national accounts and included in GDP. Green circles, arrows, and squares reflect the additional information captured by natural capital accounts. The partial overlap between natural capital accounts and national accounts reflects the fact that natural capital accounts i) measure some economic activity that is already included in national accounts, ii) measure economic activity not included in national accounts, and iii) result in a more accurate attribution of the contribution of different forms of capital to the production of goods and services that are already captured in national account. The green and red shapes' different sizes reflect the relative contribution of NCA to identifying these additional economic activities. Source: own elaboration, based on Keith et al. (2017) and United Nations et al. (2021, p. 28).

IV. Current Efforts in Natural Capital Accounting

There is a decisive global trend, including in the United States, towards implementing NCA. To this date, most ongoing initiatives are still in the pilot phase, and, as a result, the use of NCA in decisionmaking is still limited. But governments and the international statistical community are taking significant steps towards fully integrating natural capital into national accounts, with the goal of streamlining environmental-economic data in decisionmaking (Bagstad et al., 2021; Hein et al., 2020; White House, 2023, p.13).

Globally, the adoption of the System of Environmental-Economic Accounting (SEEA)—the set of guidelines set forth by the UN Statistical Commission for collecting environmental-economic data in alignment with the SNA—is a major milestone in these efforts, and it has been pivotal in countries' efforts to adopt natural capital accounts (United Nations, 2014; United Nations et al., 2021). Presently, over 90 countries have initiated NCA practices consistent with the SEEA, to various degrees of completion. Generally, European countries are leading the way in NCA, while the United States is working to catch up and meet its recent, ambitious goals (Bagstad et al., 2021; White House, 2023, p. 13, 2024). This section describes these efforts.

The System of Environmental-Economic Accounting

The System of Environmental-Economic Accounting (SEEA) is the framework adopted by the UN Statistical Commission for the integration of economic and environmental data into national accounts. The SEEA provides guidelines to measure, physically and monetarily, the relationships between the economy and the environment, and track the stocks and changes in stocks of natural capital. This information is registered in a set of connected accounts that are consistent with and can be integrated into (effectively expanding) the SNA (United Nations, 2014, par. 1.26; United Nations et al., 2021, par. 1.5). The SEEA is the result of decades of extensive cooperation between statistical offices, academics, and nongovernmental organizations around the world, and it is playing a pivotal role in global efforts to compile natural capital accounts (Hein et al., 2020, p. 514).

The SEEA consists of two complementary parts: the SEEA Central Framework (SEEA-CF) and the SEEA Ecosystem Accounting framework (SEEA-EA).[14] The **SEEA-CF** tracks emissions, physical stocks, and uses of individual natural assets (e.g., water, energy, forests, and fisheries) as well as transactions related to their management in various economic activities. It is focused on tracking the physical flows of these natural assets in and out of economic activity and assigning them a monetary value. For example, SEEA-CF provides the framework to calculate how much water is used in the economy, and how much waste, such as water pollution, is generated from this use. The UN's Statistical Commission adopted the SEEA-CF as an official statistical framework in 2012 (United Nations, 2014, p. iv).

The **SEEA-EA**, in turn, focuses on geographically explicit measurements of ecosystems and the services they generate, building on the notions of natural capital and ecosystem services described in Section 3 (United Nations et al., 2021, p.1; Hein et al., 2020, p.514). It considers ecosystems as productive assets, calling them "ecosystem assets," and organizes data in a set of accounts tracking their geographic extent, condition, usage, and value (United Nations et al., 2021, par. 2.37). This framework includes registering ecosystems' contributions to the production of goods and services using

[14] The SEEA also publishes the SEEA Applications and Extensions, which illustrates to compilers and users of the SEEA Central Framework how the information can be used in decisionmaking, policy review and formulation, analysis, and research. The SEEA–EA includes, within it, applications and extensions that are intended to guide usage of the SEEA-EA (United Nations et al., 2021, par. 1.68).

SUTs, which allows for the tracking of the use and value of ecosystem services in final consumption and as inputs in the production of other goods and services. **Figure 3** provides an example of how the SEEA-EA conceptualizes the relationship between ecosystem assets and their uses in a geographically explicit way, and the general steps towards estimating the value of ecosystem services. **Figure 4** shows the set of connected accounts in the SEEA-EA. **Table 2** in turn, presents a stylized example of an SUT that includes an ecosystems' added value along the production chain.

For ecosystem services and assets, the monetary accounts have yet to reach the statistical standard status of their physical counterparts (United Nations et al., 2017, p.3). Currently, the monetary accounts and valuations of ecosystem services and assets are only "internationally recognized principles and recommendations." In contrast, the UN's Statistical Commission recognizes the physical measurements of ecosystems in the SEEA-EA as a "statistical standard." This divergence reflects the less mature state of valuation methods compared to the measurement of the physical components of ecosystems and their services (White House, 2023, p.16).

To maintain consistency with the SNA, the SEEA (both SEEA-CF and SEEA-EA) relies on exchange values for monetization. That is, to assign monetary values, it uses the prices at which goods, services, and assets are, or could be, traded (Hein, Bagstad, et al., 2020, p. 514). Following the principles of the SNA, when direct, observable market prices are not available, the SEEA provides guidelines to assign monetary values based on common methods for valuation, including those described in **Box 5**.

Figure 3 - How Ecosystem Assets Generate Ecosystem Services

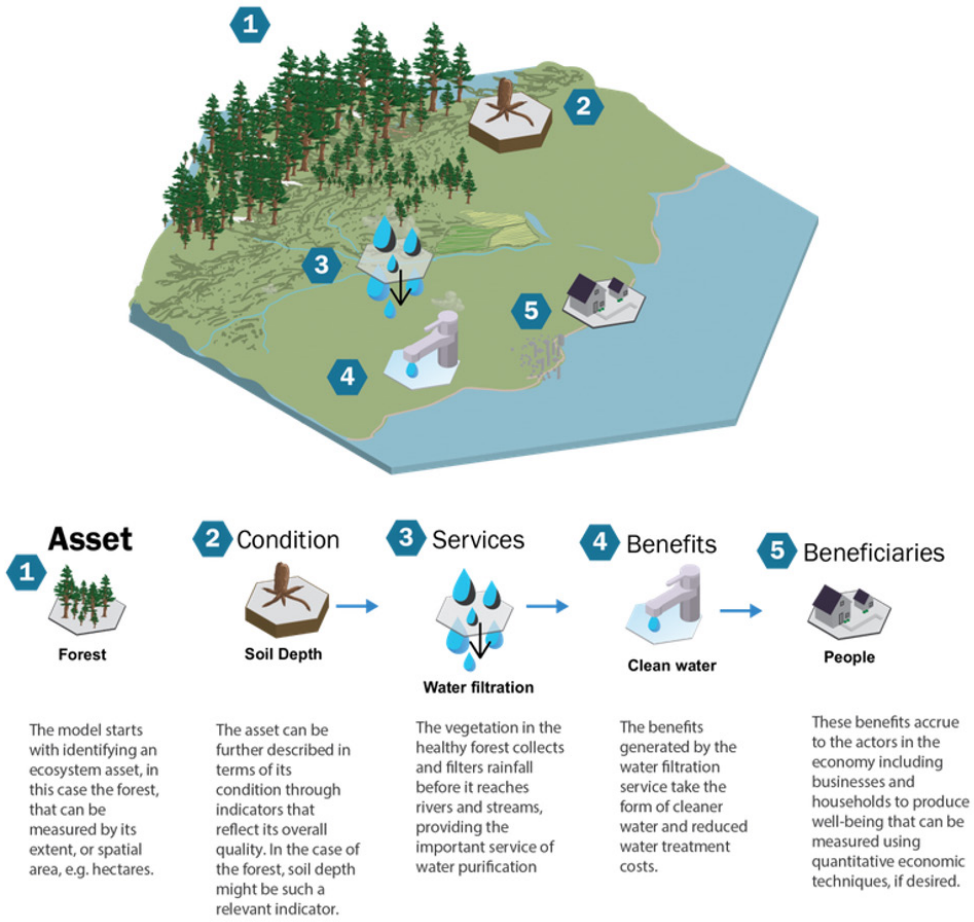


Figure 3 shows a stylized representation of the spatial nature of the SEEA-EA. It describes how a forest (an ecosystem asset that is part of natural capital) generates water filtration services, which benefits people downstream. Source: United Nations et al. (2021), available at: https://seea.un.org/ecosystem-accounting.

Figure 4 - Connected Ecosystem Accounts in the SEEA-EA

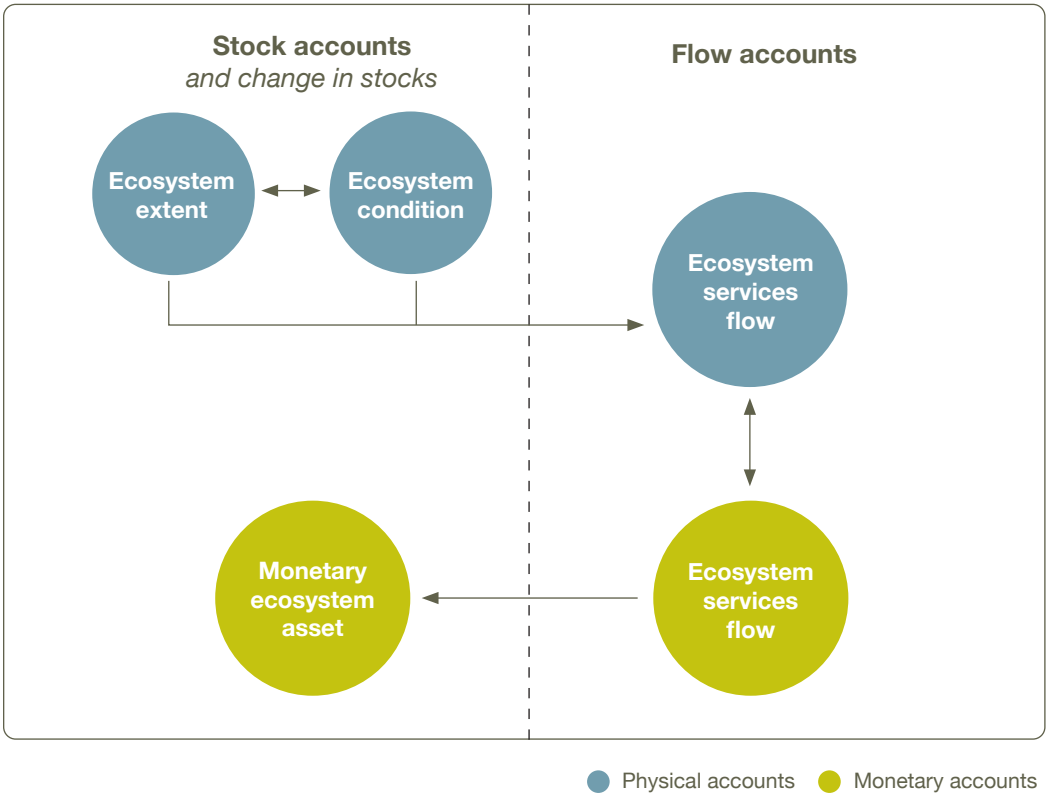


Figure 4 shows the different accounts in the SEEA-EA. **Ecosystem extent accounts** measure an ecosystem asset's area (e.g., hectares of forest). **Ecosystem condition accounts** measure an ecosystem asset's quality through a set of indicators that determine their ability to produce services (e.g., soil depth). **Ecosystem services flow accounts** measure the ecosystem services that stem from an ecosystem asset, both in physical and monetary terms (e.g., tons of timber and monetary value of the forest's contribution to timber production). These flows determine the **monetary value of the ecosystem asset** (e.g., the value of the forest). Source: United Nations et al. (2021, p. 32).

Table 2 - Extended Supply-Use Table, a Stylized Example (in Monetary Units)

	Ecosystem asset (a forest)	Forest industry	Manufacturing industry	Household final demand	Total
Supply					
Ecosystem service – air filtration	15				15
Ecosystem service – wood provisioning	30				30
Logged timber		50			50
Furniture			80		80
Use					
Ecosystem service – air filtration				15	15
Ecosystem service – wood provisioning		30			30
Logged timber			50		50
Furniture				80	80
Value added (supply minus use)	45	20	30		95

Table 2 shows a stylized example of an extended supply-use table depicting how the SEEA-EA registers the value added by an ecosystem asset (a forest). It considers two types of ecosystem services: air filtration, which is a benefit that *is not* included in the SNA, and wood provisioning, a benefit that is included in the SNA. The example builds on Table 1. Air filtration is directly consumed by households, while timber is produced and used as an intermediate good in manufacturing furniture, a final good demanded by households. The upper section shows how much air filtration and wood the forest provides and how much logged timber and furniture is supplied by the forest industry and the manufacturing industry. The lower section shows the use of air filtration and furniture by households and of logged timber by the manufacturing industry. Value added is the difference between the value of supply and the value of use. In the example, the value added by the manufacturing industry is 30 because the value at which it sells to households (80) is 30 more than the price at which they buy from the forest industry (50). Source: adapted from United Nations et al. (2021, p. 254).

The United States' Natural Capital Accounting Efforts

The United States has a rich but discontinuous history of producing environmental-economic statistics that dates back at least to the 1970s (Landefeld et al., 2010; Nordhaus & Kokkelenberg, 1999). An important landmark is BEA's publication of the Integrated Environmental and Economic Satellite Accounts in the mid 1990s, a set of accounts that included interactions between the economy and the environment and was based on existing UN guidelines at the time (Landefeld & Howell, 1998). Shortly after these were published, Congress suspended BEA's work, but it resumed it after recommendations from the Blue Ribbon Panel, which included Nobel Laureate William Nordhaus (Cavanagh et al., 2001; Nordhaus & Kokkelenberg, 1999).

In 2016, multiple agencies including the United States Geological Survey (USGS), the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), the United States Forest Service (USFS), the Bureau of Economic Analysis (BEA), and others, started to self-organize to develop natural capital account products and research. Later, in 2020, BEA independently

introduced the "GDP and beyond" initiative to improve the agency's measurement of economic activity, of which the environment is one component (Landefeld et al., 2010; White House, 2023).

All these initiatives culminated in the recent "National Strategy to Develop Statistics for Environmental-Economic Decisions," an ambitious interagency strategic plan to develop NCA and environmental-economic statistics published by the White House in January 2023. The strategy lays out a plan to progressively incorporate measurements of natural capital into official economic statistics and to have operational natural capital accounts within 15 years of its release (White House, 2023). The plan emphasizes strategic interagency collaborations, leveraging the expertise and past experiences of different agencies, and recommends a set of specific actions to be taken when constructing the accounts. A major part of the plan is to use the SEEA, where relevant and robust, as a guide in the development of the United States' accounts.[15] In doing so, the plan also recognizes the less mature state of the monetization methods in the SEEA (and in general) and identifies this shortcoming as creating a clear opportunity for the United States to lead the international community in adopting standards for valuation methods (White House, 2023, p.16).

The plan considers three phases of progressive implementation. Phase I includes accounts for land, water, air emissions, a first stage for marine natural capital, and environmental activities and jobs, which have already been the subject of research and early data compilation. Phase II includes forest accounts, which depend on the creation of land accounts and accounts for pollinators, urban green spaces, minerals, and energy, as well as the second stage of marine natural capital. Phase III, which includes accounts for wildlife, wetlands, soils, grasslands, and non-traditional assets, will enter piloting stages in 2029, as it requires data from other accounts. An important end goal of the strategy is to provide headline summary indicators, namely "Change in Natural Asset Wealth" and "Net Domestic Product inclusive of natural assets," to complement other headline economic measures, such as GDP, unemployment, and inflation (White House, 2023, pp. 31–33).

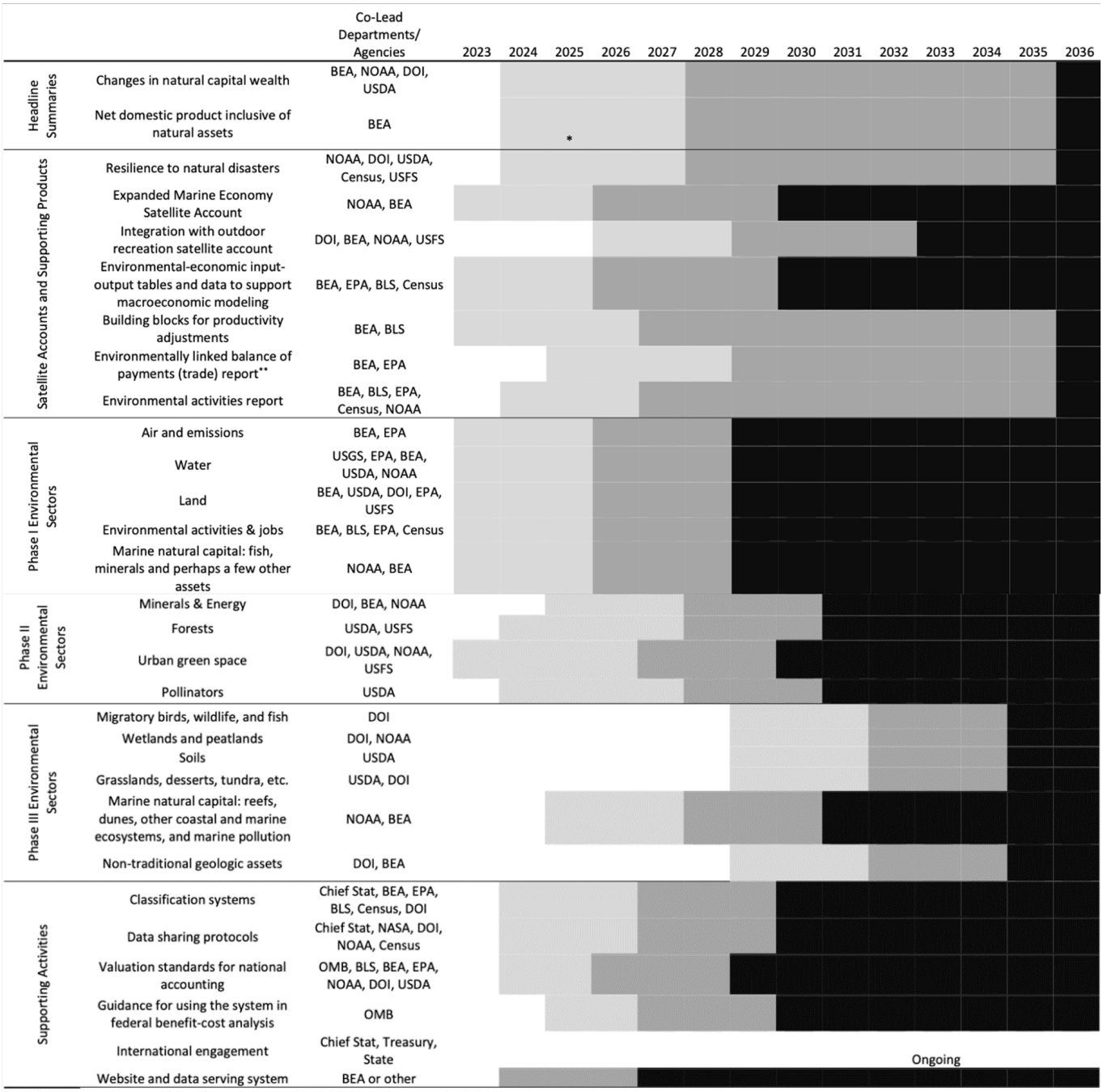
The plan contemplates the release of potentially incomplete accounts while they are in a pilot phase as well as supporting activities, such as the development of classification systems, data sharing protocols, valuation standards for national accounting, and guidelines for using the accounts in federal benefit-cost analysis (White House, 2023, pp. 62–66). **Figure 5** reproduces the Gantt chart for the United States' strategy.

Within a year of the strategy's release, agencies and researchers published pilot natural capital accounts for several environmental sectors in the United States, on schedule with the Gantt Chart established in the national strategy. Notable examples include water and land estimates under the SEEA-CF, as well as estimates for air filtration, global climate regulation, pollination, air emissions, recreation, water purification, land, and ecosystem services provided by urban natural assets, under the SEEA-EA (Bagstad et al., 2021; Heris et al., 2021; Warnell et al., 2020; Wentland et al., 2020; White House, 2024).

These efforts run parallel to recent initiatives in the United States to adopt environmental-economic information, including the value of ecosystem services, in cost-benefit analysis (OIRA, 2024; OMB, 2023).

[15] Federal agencies already gather a significant amount of data required for the development of natural capital accounts. However, this data is not organized in a way that facilitates the linkage between the environment and the economy. Part of the current effort is then to reorganize existing data. Significant effort is also devoted to collect additional information that is currently unavailable (White House, 2023, p.38).

Figure 5 - Gantt Chart for the United States' National Strategy to Develop Statistics for Environmental-Economic Decisions



*Pending expected new guidance from the international statistical community in 2025.
**May articulate to the G20 data gaps initiatives.

Generally, departments are listed when either the main office (e.g., chief economist's office) or multiple agencies are involved. BEA is called out within DOC because of its broad leadership role. NOAA and Census are called out within DOC because of uniqueness within DOC. USFS is separated from USDA because of its unique role within USDA. Department and agencies listed include: Bureau of Economic Analysis (BEA), Bureau of Labor Statistics (BLS), Census Bureau (Census), Chief Statistician of the United States (Chief Stat), Department of Interior (DOI), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), Office of Management and Budget (OMB), Department of State (State), Department of the Treasury (Treasury), Department of Agriculture (USDA), Forest Service (USFS), United States Geological Survey (USGS).

Figure 5 reproduces the Gantt chart for the United States' national strategy to develop statistics for environmental-economic decisions. White indicates research activities, light gray indicates pilots and first versions, dark gray indicates prototypes or second versions, and black indicates core statistical series inclusion or finalized methodologies. Source: White House (2023, p. 31).

Natural Capital Accounting Efforts in the Rest of the World

To date, Europe has been at the forefront of piloting natural capital accounts, with the United Kingdom and the Netherlands leading the way. Both have published the value of several ecosystem services and natural assets for several years.

In 2022, the United Kingdom, for example, valued annual ecosystem services at more than $50 billion (measured in 2024 USD), with a total value of natural assets of around $1.9 trillion. Impacts on health are the largest identified benefits associated with these services, with health benefits from recreation (valued at around $500 billion) being the largest contributor to total natural asset value. These natural capital accounts provide, alongside monetary values, physical measurements of the different ecosystem services, as recommended in the SEEA. Land values are incorporated into the United Kingdom's balance sheet and have been used to design and monitor land and forest policy (Bass et al., 2017; Ruijs et al., 2019).

The Netherlands also publishes natural capital accounts consistent with SEEA and has estimates for the period from 2013 to 2018, which have already informed policymaking. For example, the Dutch government used water accounts to quantify water use by economic sectors and evaluate the efficiency of its use, considering pollution intensity. It also used these estimates to set water-related taxes and determine each sector's appropriate contribution to the recovery costs of water provision services. Moreover, it used energy accounts to develop and monitor its decarbonization efforts by linking energy supply-use tables to other environmental accounts, such as air pollution and the value of natural gas and oil reserves (Hein, Remme, et al., 2020).

In addition to countries' individual efforts, Europe has important continental initiatives to compile natural capital accounts (Bright et al., 2019; Hein, Bagstad, et al., 2020). For example, since 2017, Eurostat has co-funded SEEA-EA projects in multiple member states. In addition, the Integrated Natural Capital Accounting (INCA) initiative, a project by the European Commission aimed at supporting the development of the SEEA-EA, has produced estimates at continental scales. It provided estimates for seven ecosystem services within the EU, the aggregate value of which was estimated to be around €170 billion per year in 2012. Water purification, nature-based recreation, and crop provision were the most significant services, accounting for approximately €56 billion, €50 billion, and €21 billion annually, respectively (Vallecillo et al., 2019).[16] The INCA initiative demonstrates how large-scale ecosystem services data can be clearly communicated to the public with the use of summary statistics, maps, and tables (Vysna et al., 2020).

Other countries, including Mexico, Brazil, Australia, Indonesia, Japan, and India, have published SEEA accounts. In some cases, these accounts have been used for policy. Indonesia for example, used its carbon accounts to assess changes in peatland ecosystems. South Africa used its natural capital accounts to inform national water sanitation plans. Colombia used its natural capital accounts to calculate water fees and assess damages caused by El Niño. Australia and Canada are also actively engaged in NCA efforts and are official partners of the United States in these endeavors (Ruijs et al., 2019; United Nations Statistics Division, 2023; White House, 2024).

[16] As opposed to the United Kingdom's estimates, INCA omits health impacts from its calculation of the value of water purification or nature-based recreation services. Instead, it focuses on replacement cost methods to value water purification (the cost of building a water treatment plant in case these services disappear) and travel costs to calculate the value of nature-based recreation services.

V. Uses and Users of Natural Capital Accounting

NCA can have substantial impacts on governments, businesses, and the public's decisionmaking. Broadly, NCA will allow for a better representation of connections between economic activity and nature (United Nations et al., 2021, par. 1.63). Countries' and businesses' balance sheets will be more accurate, better reflecting the uses and value of nature and ultimately leading to better decisionmaking (Boyd et al., 2018).

Countries have historically adapted their national accounting frameworks to the relevant policy questions of the time (Landefeld et al., 2010). In fact, national accounts were first conceived in the United States to respond to the need for measuring income during the Great Depression and were later expanded to track production during and after World War II (Marcuss & Kane, 2007). In the same vein, NCA is a response to the need for measuring the connections between the economy and nature in light of the environmental challenges of our era (Hein et al., 2020; White House, 2023; World Bank, 2021, p. 33).

Measuring and monetarily valuing the connections between the economy and the environment is a complex endeavor in early phases of implementation. As such, it will require substantial research and experimentation before it realizes its full potential. Part of that process involves describing its potential uses, which we do in this section.

General Uses of Natural Capital Accounting

A key feature of NCA is that it measures ecosystems and their services using a common metric: money. Thus, NCA clarifies the relative value of different natural assets and their services, enabling comparisons between them as well as with other forms of capital. These comparisons inform users about tradeoffs and complementarities between different forms of capital, enabling the rational use of natural and other resources. For example, natural capital accounts can be used to evaluate whether a country should allocate more of its national forests for timber instead of preserving it for other services, such as water filtration, carbon sequestration, or recreation (or the opposite) (Farber et al., 2002; Fenichel et al., 2016; Keith et al., 2017; Rouhi Rad et al., 2021).

Since determining nature's contributions in monetary terms is challenging, decisionmakers often implicitly value them at zero, which results in overuse and a perception that conservation is a cost rather than an investment (Fenichel et al., 2016). By calculating their monetary value, NCA can effectively unveil the costs of reducing the supply of goods and services provided by nature. In doing so, it can also help dispel the implicit assumption in existing public dialogue of an inherent tradeoff between environmental preservation and economic production (Bateman & Mace, 2020; Rouhi Rad et al., 2021).

NCA can also help assess whether an economy is sustainable (see **Box 1**). Sustainability is often defined in two forms: weak and strong. Weak sustainability suggests an economy is sustainable if the monetary value of all forms of capital is sustained over time. This definition assumes that the different forms of capital are perfect substitutes. For example, cutting down a forest to build a school that increases human capital can sustain higher well-being for future generations. Strong sustainability in turn highlights the limited substitution of the different forms of capital and defines an economy to be sustainable if the physical quantities of different forms of capital are not decreasing over time. Because a pre-requisite for the monetary valuation of natural capital is the physical measurement of ecosystems, NCA can bring important insights into whether the economy is sustainable, under any of the two definitions described above. (Arrow et al., 2004;

Dietz & Neumayer, 2007). NCA can thus be an important contribution to current (and future) policy debates and business strategies centered on sustainability (Lu et al., 2015; Whelan & Fink, 2016).

Relatedly, NCA plays a crucial role in developing indicators of economic activity that extend beyond GDP. Economists have long advocated for increased focus on measures such as Net Domestic Product (NDP), which subtracts (or adds to) GDP the reductions (or accumulations) of capital assets. NCA enhances our NDP measures by expanding the forms of capital included in their calculations, resulting in more accurate approximations of changes in well-being and sustainability (K. Arrow et al., 2004; Bagstad et al., 2021; Stiglitz et al., 2009, p. 514). As discussed above, one of goals of the United States' natural capital accounting efforts is developing a measure of NDP inclusive of changes to natural assets (White House, 2023, p. 33).

Businesses

Businesses can use NCA to evaluate risks and opportunities (Giglio et al., 2023; Ingram et al., 2022; Natural Capital Coalition, 2016, p. 6).[17] NCA can directly inform strategic planning, investment decisions, supply chain management, operations management, risk management, and corporate reporting (Ingram et al., 2022, p. 1). For example, food producers and retailers are interested in knowing trends in pollinator populations and soil quality, both of which may affect future agricultural productivity and food prices or prompt relevant policy changes. NCA provides businesses with standardized, systematic, and regular measurements to evaluate these risks related to natural capital, which is lacking (Flammer et al., 2023; Giglio et al., 2023).

Many businesses are starting to conduct natural capital assessments following guidelines like the Natural Capital Protocol (Natural Capital Coalition, 2016).[18] In some cases, their interest in measuring, managing, and reporting on natural capital is increasing faster than available data (Dixon et al., 2022; Ingram et al., 2022, pp. 2 & 7; White House, 2023, p. 9). Again, the absence of comprehensive and consistent information has impeded businesses' ability to integrate environmental-economic information into their assessment of environmental risks and thus guide their decisions (Ingram et al., 2022, p. 3, 2024).[19] By providing guidance for the measurement of ecosystems and their relationship to the economy, NCA can improve businesses' natural capital assessments and support many initiatives currently striving to recognize the importance of ecosystems and biodiversity for their operations.[20] At the same time, businesses can actively contribute to the development of these accounts, aligning them with potential business uses and identifying data gaps (Ingram et al., 2022, p. 8).

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[17] Risks in this context are usually classified as either "physical" or "transition" risks. Physical risks are those related to changes in the physical components of ecosystems and how they may affect businesses, such as the direct impacts of soil erosion on agricultural yields or water quality and what they mean for the food industry. Transition risks stem from changes in policy, such as tightening regulation on pollution (Giglio et al., 2023; Ozturk et al., 2022).

[18] For example, Nestlé has used natural capital assessments to pay premiums to farmers that invest in natural capital. Danone has used natural capital assessments to calculate carbon-adjusted earnings (Mohr & Thissen, 2022).

[19] The documentation and understanding of businesses' dependencies on ecosystems are on the rise. Notably, recent research has shown that financial markets are factoring in risks related to biodiversity loss and climate change when determining the value of shares and other financial assets (Giglio et al., 2023; Schlenker & Taylor, 2021; White House, 2023, p. 9). Natural capital accounting can be an important tool for evaluating these risks.

[20] For example: the Capitals Coalition, Global Reporting Initiative (GRI), International Integrated Reporting Council (IIRC), Sustainability Accounting Standards Board (SASB), World Business Council for Sustainable Development (WBCSD) (United Nations et al., 2021, para. 1.65).

Government

Federal, state, and local governments are likely to become primary users of NCA. Government agencies already use national accounts extensively, but they are flying partially blind with respect to the environmental-economic impacts of their policies. These same government agencies are likely to use natural capital accounts to identify environmental-economic issues and design, implement, and monitor policy responses, and determine whether objectives are met (Bass et al., 2017; Ruijs et al., 2019; United Nations Department of Economic and Social Affairs, 2021, p. 15; Vardon et al., 2016). As mentioned above, NCA complements ongoing efforts in the United States to incorporate ecosystem services and natural capital valuations in benefit-cost analysis (OIRA, 2024; OMB, 2023).

Government agencies (as well as researchers) also widely use national accounts to feed empirical and simulation models that analyze policy impacts. NCA can be used to study interactions between the economy and nature that are currently absent in these models, informing the choice, design, and evaluation of different policy alternatives. In these models, NCA can provide information on how changes in natural assets ripple throughout the economy (and vice-versa), providing vital information for all kinds of policy questions (OIRA, 2024, p. 24; Ruijs et al., 2019, p. 718; United Nations Department of Economic and Social Affairs, 2021, p. 33; White House, 2023, pp. 64–66). For example, central banks can use NCA to quantify the uses of natural capital by different sectors and evaluate the systemic risks associated with climate change, biodiversity loss, and policy responses that include the interaction between economic and ecological systems (Agarwala & Zenghelis, 2020, p.33; Ruijs et al., 2019, p.718).

Despite its national focus, NCA can support decisionmaking at multiple spatial scales. Specifically, while NCA primarily focuses on collecting, aggregating, and presenting information at the national level, the use of spatially explicit data means that NCA can also support policy at more local levels. Thus, the ability to disaggregate NCA data can support cost-benefit analysis and other policy-evaluation approaches at multiple spatial scales, including state and local governments (OIRA, 2024; OMB, 2023; United Nations et al., 2021, para. 1.64; White House, 2023, pp. 8, 64 & 65). Relatedly, NCA can be a key input for distributional analysis, an important new focus in policy debates in the United States and abroad (OMB, 2023). For example, because of its spatially explicit nature, NCA can be particularly useful in revealing how the costs of environmental degradation, the benefits of ecosystem services, and natural wealth are distributed across different population groups (Atkinson & Ovando, 2022; Fenichel et al., 2016).

The Public

NCA can provide important information to the public. In principle, having consistent information on ecosystems, their condition, and how they are used for economic activity can provide grounds for civil society groups to organize and participate in discussions about natural resource management (Ostrom, 2009). Also, NCA can serve as a tool for government accountability by providing information on, for example, the effectiveness of natural asset management by authorities or the evolution of economic growth inclusive of natural capital depreciation (Boyd et al., 2018; United Nations et al., 2017, para. 2.6). This has the potential to influence the political cycle, much like GDP, which plays an important role in evaluating the performance of elected officials and setting candidates' agendas (Boyd et al., 2018, p. 940).

VI. Challenges, Limitations, and Future Directions

Historically, national accounts have adapted to the challenges of the time. They were first conceived in the United States to measure income during the Great Depression, and they were later expanded to measure production during World War II (Marcuss & Kane, 2007). Natural capital accounts aim to make the connections between nature and the economy explicit, enabling more comprehensive measurements of production, income, and wealth that incorporate natural capital's uses and value (United Nations et al, 2021, par 1.3; White House, 2023). In this sense, NCA efforts should be seen as a necessity for properly managing and evaluating economic performance, where the connections between nature and economic activity need to explicitly recognized. These new expansions of national accounts are pivotal for society's efforts to tackle climate change and biodiversity loss, two great challenges of our time (Hein et al., 2020; White House, 2023, p.33).

NCA is still in the early phases of a long implementation process and will realize its full potential only when natural capital accounts are comprehensive and regularly updated. Achieving that goal will require significant and sustained efforts from statistical agencies, in collaboration with researchers, NGOs, businesses, and the public (Bass et al., 2017; Hein, Remme, et al., 2020; Ingram et al., 2022, 2024; Ruijs et al., 2019). During this process, NCA will face implementation challenges related to the inherent complexities of natural capital valuation and accounting, technical and institutional constraints, and the lack of political will (Brandon et al., 2021, p. 147; Hein, Bagstad, et al., 2020; Vysna et al., 2020). These challenges include interpreting, communicating, and ultimately using the accounts for decisionmaking. In this section, we highlight some important issues in NCA, shed some light on the interpretation of the accounts, suggest avenues of research, and explain the challenges NCA efforts may face in their implementation.

Uncertainty

Compared to current national accounts, natural capital accounts have relatively high measurement error (United Nations et al., 2021, para. 2.90; Vardon et al., 2016, p. 5; Venter et al., 2024). This occurs because NCA requires modeling the behavior of complex socio-ecological systems, combining knowledge from multiple disciplines, like economics and the natural sciences, and using models and remote sensing techniques, all of which are subject to potentially large measurement errors (Hein, Bagstad, et al., 2020, p. 515). In contrast, national accounts use relatively more precise estimations and do not rely on models, estimations, or proxy indicators. These measurement errors and the inherent uncertainties in the biophysical and monetary components of NCA compound, and pose important challenges to their implementation. While relevant, the measurement challenges in NCA are not insurmountable as demonstrated by the success in developing estimates for the social costs of greenhouse gases (IWG, 2021).

Despite its relative complexity, there are currently no clear guidelines on how to communicate the uncertainty underlying NCA, which may affect both its credibility and its uptake by some potential users (Venter et al., 2024). The statistical community, including natural capital account developers in the United States, is aware of this challenge and is actively developing best practices for assessing and reporting uncertainty in ecosystem accounting (Vardon, 2013; Venter et al., 2024). For example, a guiding principle in the United Kingdom's NCA system is to provide transparent confidence levels in their estimates and be explicit about both gaps in the types of services that are covered and about the potential for over- or understatements (Office for National Statistics, 2017). Proper communication of these uncertainties will be key for the uptake of natural capital accounts as well as for their correct interpretation, suggesting important and urgent avenues for future work (Vardon, 2013; White House, 2023, p. 16).

Non-Marginal Changes

In NCA, monetary measurements are based on the exchange value concept, which is necessary for maintaining consistency with national accounts. Using exchange values implies that an ecosystem service is monetized based on its marginal value—that is—on the value of small changes in the provision of the service. Because the marginal value of any good or service changes with the quantity consumed, monetary valuations in NCA provide limited insights into welfare changes resulting from substantial changes in the provision of ecosystem services, including the crossing of ecological thresholds (tipping points) (Costanza et al., 1997; Dasgupta, 2021; United Nations et al., 2021, para. 10.4).[21]

For example, a natural capital account might report how much water there is in a particular water body and how much water it is expected to provide to a population in the future. NCA estimates the water body's monetary value by multiplying the amount of water provided (e.g., cubic meters) by its value per unit (e.g., USD per cubic meter). This unit value is recovered based on the value of marginal (small) changes to the provision of the ecosystem services, such as what value would be lost (or gained) if the water body had a little bit less (or more) water than it currently has.[22] This unit value is, however, likely to change with large changes in the provision of the service. If policymakers and others show interest in knowing the value of the total water body and the cost of its complete disappearance, the use of the monetary values of natural capital accounts can be problematic because it would not consider the changes to the marginal values resulting from large changes in the provision of the services.[23]

NCA is, however, still relevant for assessing non-marginal changes for at least two reasons. Firstly, NCA builds upon information on the physical components of ecosystems and their uses. Thus, it can tell us if physical changes are non-marginal in nature, such that other valuation concepts are necessary, and provide the physical estimates to be used with other valuation methods that consider changes in marginal values, such as changes in consumer-surplus, which are regularly used in cost-benefit analysis (White House, 2023, p. 65). Secondly, NCA can provide lower (or upper) bound estimates of the value of environmental losses (or gains), because the marginal value increases (or decreases) when the quantity decreases (or increases) (OIRA, 2024; OMB, 2023; United Nations et al., 2021, para. 8.4).

Relative Prices

To estimate the value of the stock of natural capital, NCA requires analysts to estimate the value of ecosystem services in the future. The default approach in NCA is to assume that the current period price will apply in future periods (United Nations et al., 2021, par. 10.61). This approach's suitability is based on prices accurately reflecting all currently available information about the future, including the evolution of all the relevant forms of capital that jointly determine the provision of ecosystem services. In the case of non-market goods and services, this assumption likely does not hold. In particular, as ecosystems get depleted, environmental goods and services will become scarcer relative to goods and services sold in the marketplace, and their relative value is likely to increase. This "relative price" effect greatly impacts the value of natural capital, but is unlikely to be incorporated in NCA (Drupp et al., 2024). Adjusting for relative prices poses an in-

[21] Economic theory typically assumes that the marginal value (how much a good or service adds to benefits) decreases (increases) when the quantity consumed increases (decreases). This is the basis of downward sloping demand curves, in which the quantity consumed increases (decreases) when the price decreases (increases), a foundational construct of economic theory.

[22] This unit value is obtained through the methods illustrated in **Box 5**. For example, by estimating how agricultural production changes with small changes in water provision, or the additional costs of treating additional water pollution in a treatment plant.

[23] Note that this issue is also present in the interpretation of current national accounts, as they also rely on the use of the exchange value concept. This is not necessarily a problem of national accounts or NCA, but rather an important consideration in their interpretation. One way that economists address these non-marginal changes is by using computable general equilibrium (CGE) models that allow for prices to change (Burfisher, 2021).

teresting challenge for the implementation and interpretation of NCA. This is a relatively new area of research, of which NCA can be both a beneficiary and a contributor, that should be further pursued.

Cost

The interdisciplinary nature of NCA and the relative complexity in the underlying information will require agencies to develop technical expertise they often lack (Bagstad et al., 2021). Thus, countries may face technical and budgetary constraints in their efforts to gather and process this new data. Acquiring the technical capabilities, including by hiring technical staff, will be an important challenge for agencies. Agencies should consider this specific challenge in their medium- and long-term planning.

At the same time, businesses and governments may require data for decisionmaking at finer temporal and spatial resolution than is currently feasible (Hein, Bagstad, et al., 2020, p. 515; Ingram et al., 2022, p. 9). Thus, producers and users of the accounts will need to balance timeliness and accuracy of the data (Vardon, 2013). The increasing amount of public remote sensing (satellite) data, coupled with replicable computational models, for example, can play a big role in scaling up NCA efforts and reducing this tradeoff (Brander et al., 2022; Hein, Bagstad, et al., 2020, p. 515).

Then, agencies and researchers developing natural capital accounts should consider the social benefits (to other agencies or researchers) of providing replicable methods that can help other agencies and countries in reducing the costs of their NCA efforts.

Incomplete Accounts

Related to the above, decisionmakers will likely start using the values recorded in natural capital accounts as they become available, causing additional challenges and risks during the transition to comprehensive and consistent accounting. Some services, namely those that are easier to quantify, will probably be integrated earlier in the transition. In addition, some services may be subject to more and more persistent measurement errors than others. The progressive incorporation of the different ecosystem services in the transition to complete accounting, coupled with the fact that humans tend to devalue more uncertain values, may result in some services being favored in decisionmaking, both during the transition and in the long run. For example, a forest's relatively certain and easy-to-calculate value as a source of timber or carbon sequestration is more likely to be included earlier in the accounts, and it may be given more weight than its relatively uncertain value as a biodiversity supporter (Trimmer et al., 2011). This imbalance has been a concern in the development of carbon offset markets, where carbon sequestration service providers may be incentivized to plant monocultures (which carry adverse biodiversity impacts) if the latter are not incorporated in NCA and policymaking in a timely fashion (Bekessy & Wintle, 2008; Hulvey et al., 2013). Decisionmakers will then have to balance this inherent uncertainty with the pressures of incorporating the new information from natural capital accounts. Whether natural capital accounts will improve decisionmaking in the interim will depend on how developers and the research community at large educate users and develop guidelines that consider these challenges.

VII. Conclusion

Natural capital accounts have the potential to substantially improve the decisionmaking of policymakers, businesses, and the public. This ability, however, is not guaranteed by the mere development and existence of the accounts, as the examples outlined above try to illustrate. It can certainly be an important step in that direction, especially if they incorporate additional improvements as early as possible. Of particular importance are improvements in valuation methods and the education of users that can guide the interpretation of the accounts. Just as national accounts continue to improve and advance methods, this will be true for natural capital accounts, even more so given their relative newness. Thus, the continuous education of users and the careful development of implementation guidelines should be a priority, especially during the transition to comprehensive accounting.

Despite these limitations and the relative nascence of NCA, policymakers, businesses, and the public have great interest in developing natural capital accounts (Bagstad et al., 2021; Hein, Bagstad, et al., 2020). Their demand from the different users and their supply by statistical agencies (and researchers) feed each other in a potentially virtuous cycle (Vardon et al., 2016). So, demonstrating the benefits of using these accounts can motivate governments to further develop them. Simultaneously, compiling new accounts will increase their demand as their utility becomes evident. Continuous collaboration among statistical agencies, academics, international organizations, businesses, and non-governmental organizations could further foster this virtuous cycle. This collaboration has been a cornerstone in developing accounting standards in the past and will continue to be pivotal in advancing NCA in the future (Bagstad et al., 2021, p. 12).

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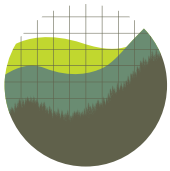

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