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THEMATIC ESSAY

ON NATURAL CAPITAL

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Abstract: This paper provides a brief on the economics of biodiversity. The human economy is seen here as being embedded in the biosphere, which is an all-embracing planetary capital asset. Ecosystems are components of the biosphere; hence, they are considered forms of 'natural capital'. The economics of biodiversity thus constitutes the study of a specific class of asset management problems. Theoretical reasoning and empirical findings tell us that human activities have given rise to ecological overreach, breaching the safe operating space of our planetary boundaries. In effect, we have been overdrawing the global stock of natural capital. The underlying reason for the increasing overdraft is the under-pricing of natural capital. The implications of this for our economic prospects are the subject of this paper.

Keywords: Natural Capital; Biodiversity; Impact Inequality; Ecosystem Services

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[1] The paper is based on a lecture I delivered at the 25th anniversary celebrations of the South Asian Network of Development and Environmental Economists (SANDEE) in Kathmandu, 12–14 December 2025. My understanding of the economics of natural capital have sharpened over the years while lecturing on the environment and economic development at SANDEE's annual teaching workshop, held at the Asian Institute of Technology, Pathum Thani, Thailand. The present paper is built on my review of the economics of biodiversity for the UK Treasury (Dasgupta 2021 online; Dasgupta 2024 hardcover), a non-technical version of which was published in the UK and Europe (Dasgupta 2025) and has appeared in the US in January 2026 (Dasgupta 2026). I am grateful to Paul Ehrlich, Enamul Haque, Simon Levin, Pranab Mukhopadhyay, Mani Nepal, Subhrendu Pattanayak, Peter Raven, Priya Shyamsundar, E. Somanathan, Thomas Sterner, Jeff Vincent, and to participants at the SANDEE workshops over the years, too numerous to mention individually, for the many discussions I have had with them. Above all, I am grateful to the late Karl-Göran Mäler, for educating me on the economics of natural capital. Mäler (1974) is the classic on the subject. His death, in 2020, marked the end of the first phase of SANDEE's activities. A founder of SANDEE, his involvement with us had always been complete and generous, while his impatience with "loose thinking" kept us all alert. This essay is dedicated to his memory.

1. INTRODUCTION

In Spring 2019, I was asked by Philip (now Lord) Hammond, then chancellor of the United Kingdom's exchequer, to write a review of the economics of biodiversity. Behind the invitation was no doubt the feeling, widely shared by the public, that something is not right with the character of economic development the world has experienced in recent decades, for it has been accompanied by continual degradation, even desecration, of the natural environment, or what we today call 'natural capital'. Climate change is one sign of that worldwide degradation; biodiversity loss is another. These are all part of the planetary boundary framing and discourse on 'safe operating space' (Steffen et al. 2015, Rockström 2009).

Accepting the chancellor's invitation was easy, as I had been working for more than four decades around the idea of biodiversity, specifically on themes at the interface of human population, their living standards, and the environment around us. I recognize that 'biodiversity loss' is a catch-all phrase that expresses a decline in the productivity of ecosystems in general, that is, the ability of ecosystems to produce the goods and services lying at the very core of the human economy and well-being and of our very existence. However, I also knew what the chancellor had asked for could not be a 'review', for there were no economics of biodiversity to review. One could find a substantial body of work in what is known as 'environmental and resource economics', but it hadn't yet been put together to create something that could be called 'the economics of biodiversity'. Among other things, human population numbers were taken as a given in such studies, so possible demographic pressures on the biosphere were not discussed. But even that limited literature was foreign to growth and development economics and to the economics of poverty. As taught and discussed in academia and practised by national treasuries and international organizations, received economics mentions Nature only in asides.

2. THE UN SUSTAINABLE DEVELOPMENT GOALS

This negligence is reflected in the United Nations' Sustainable Development Goals (SDGs). Adopted in 2016 by the member countries, the 17 SDGs (Figure 1) were meant to be attained by 2030.

Figure 1: The UN's Sustainable Development Goals (SDGs)

Source*:* United Nations, published without a copyright notice. Downloaded from https://commons.wikimedia.org/wiki/File:Sustainable_Development_Goals.png

The intention is noble, but the attempt reads as a desire to square the proverbial circle. For example, unless ways are found to reduce the quantity of natural capital that the global economy draws on to produce sufficient GDP, SDG 8 (GDP growth) cannot be consistent with SDGs 14–15 (to conserve and regenerate life in the sea and on land).

Notably, no SDG exclusively addresses freshwater ecosystems unfortunately; SDG 14 refers exclusively to marine life. Freshwater biodiversity conservation is only Target 6 ("protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes") of SDG 6 ("Ensure Availability and Sustainable Management of Water and Sanitation for All". The absence of an exclusive SDG for freshwater ecosystems and biodiversity is now considered a deliberate omission, due to push back from countries and the large political economy around water infrastructure.

The SDGs also do not unpack the constituent factors of the global demand for Nature's goods and services, nor do they compare them to Nature's ability to meet this demand sustainably. Moreover, the framers of the SDGs did not ask whether the goals, even if they were to be realized, would be sustainable. In the event, only four of the goals (e.g., SDG 1, eliminating absolute poverty) are on track to be achieved. The principal weakness of this approach is that it doesn't build on the idea that economic development involves the management of capital assets. In the rest of this paper, I sketch a formulation of the idea of sustainable development that does not suffer from these deficiencies. Briefly put, *sustainable development should be read to mean an economic path along which wealth, which is the social worth of an economy's entire set of capital assets, grows over time* (Dasgupta and Mäler 2000). But for brevity, I focus in this paper on the natural capital contained in an economy's wealth.

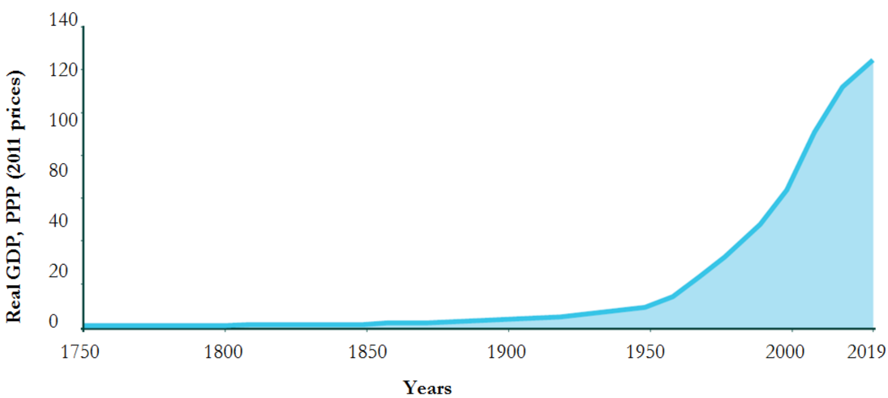
3. EXPLAINING THE ABSENCE OF NATURAL CAPITAL IN MAINSTREAM ECONOMIC REASONING

I should first explain why environmental and resource economics, or what I refer more comprehensively to as 'ecological economics', ignore vital factors driving economic change (such as human population numbers), and why the body of economic thinking ignores ecological economics. Research in economics, as (I imagine) in other scientific disciplines, mostly involves working on problems others are also currently working on. Each publication is an incremental step forward from what is already extant. If the biosphere (I am using 'Nature' and 'biosphere' interchangeably) had been included when models of long-term economic development and, by extension, the economics of poverty were being constructed in the 1950s and 1970s, the dominant mode of economic thinking today would have been very different, and I would probably not be writing this paper now. There are five interconnected reasons it wasn't included.

First, ecology, as it has developed in recent decades, was in its infancy in the 1950s, and few ecologists at the time examined signs of strain at a planetary scale. That they didn't is owed to the second reason: in the immediate post-World War years, the global economy was not large enough to have stretched the biosphere's outer limits (Figure 2).

These two were aided by a third reason: Western economies, for a long while, outsourced their 'biodiversity needs' to poor, tropical countries. If the supply source of a primary product dried up at one place, there would be another place to go to, or there would be scope to develop substitutes domestically, perhaps using a different set of primary products from another foreign source. Degradation of local ecosystems in the tropics had been alarming even then, for many rural communities in the tropics experienced the consequences of biodiversity loss; but because global economic models developed in the West had percolated down everywhere, official thinking on poverty and development, including that of decision-makers in countries supplying these primary products, considered Nature as infinite in scope and capacity.

Figure 2. Global Real GDP (2011 prices) in trillions international dollars 1750–2019



Source: Adapated from Dasgupta (2021)

There was a related, fourth reason: economics as a discipline coevolved with the Industrial Revolution, beginning from around the second half of the eighteenth century. The idea of 'progress' was in the air; it wasn't a time when the public could be persuaded about our embeddedness in a bounded biosphere.

Indeed, the fifth reason mainstream economics has ignored natural capital is that the post-World War world has enjoyed unprecedented success in raising standards of living. Today's economic landscape would have been wholly unrecognizable in 1950. The global economy has grown more than 15-fold, per capita income has increased by five-fold to the current 20,000 international dollars a year, and absolute poverty has declined from around 60% of the world's population to under 10%—all despite the global population having increased from 2.5 billion to more than 8.2 billion. As economic commentators in recent years have repeatedly observed in books and essays, humanity has never had it so good. Figure 2 displays this remarkable 75-year post-War global economic experience.

This extraordinary achievement was made possible by the accumulation of produced capital (e.g., roads, ports, buildings, machines, dams), human capital (health, education, aptitude), and ideas (science and technology). The accumulation process transformed entire landscapes into agricultural fields as far as the eye could see, with gleaming metropolises across the globe. That success has influenced the framing of economic problems and the search for ways to spread the good fortune to those who have been left behind.

But our global success has come at the cost of an increasingly impoverished biosphere, due to the effects of mining, quarrying, and land-use changes. One sign of that impoverishment is the extinction of species, currently at 100–1,000 times the average extinction rate of the previous several million years. Another sign is the decline in the biosphere's ability to sustainably meet our demands for its goods and services (see below, for quantitative evidence). The character of the global economy can thus be visualized as a coin, with one side displaying skyscrapers, factories, plantations, agricultural fields, animal farms, and highways in all parts of the world, and the other side depicting shrunken lakes and wetlands, dead oceanic zones, desiccated forests, vanishing grasslands, bleached coral reefs, degraded soils, and infertile watersheds.

If that other side is even now absent from received economics (the major economics journals almost never publish articles on the economics of natural capital), it is because today's decision-makers, both in private and public institutions, are yesterday's students. The combined influence of academic economics and decision-making on the world at large, and the depth of their combined imprint on the public's imagination, is hard to overestimate. If natural capital continues to be mostly absent from the official economic reckoning today, it is because Nature has been absent from economics all along.

I felt that absence vividly some years ago (2011–12), while chairing an expert group convened by Jairam Ramesh, then union minister for rural development, Government of India. Our task was to develop a framework that included natural capital in national accounts. I convened three day-long meetings in Delhi before putting pen to paper (Dasgupta *et al.* 2013), but the chief economist from the Ministry of Economic Affairs, an ex officio member and signatory to our report, attended only one meeting, that too for less than 30 minutes, and spent even that time signing documents his office assistants periodically brought to him. He did make one remark though, and it was that time is discrete, not continuous. The relevance of that observation for what we were discussing baffled me then and remains mysterious to me even now. But it illustrates the extent to which development expertise among establishment economists has become ossified. It is easy enough to forget now the effort that the small band of ecological economists of that time had to make to be heard over dominant voices representing mainstream economics, even mainstream development economics.

4. THE IDEA OF SUSTAINABLE DEVELOPMENT

In 1987, the World Commission on Environment and Development published *Our Common Future*, commonly known as the 'Brundtland Report' (Brundtland 1987). The now-classic publication defined 'sustainable development' as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". I don't know of another idea in growth and development economics or the economics of poverty that caught the public imagination as quickly as the notion of sustainable development, but it deserved its immediate acceptance as a tool for thinking about future economic possibilities.

The Brundtland criterion asks us to compare economic opportunities at different points in time and defines sustainable development as paths along which those opportunities expand continually (or, more accurately, don't ever contract). Because there are several sustainable development paths—the criterion does not prefer any particular composition of capital assets across the many potential paths along which opportunities expand continually—we would need additional criteria to choose among them. The Brundtland criterion should thus be thought of as a basic requirement, nothing more.

Advocates of economic (read: GDP) growth could, of course, respond by insisting that it is *because* GDP growth creates economic opportunities that national governments should pursue it. The problem with this argument is that the 'G' in GDP represents 'gross', meaning that the depreciation of capital assets accompanying economic activity is not included. It could be that GDP is increasing in any economy even as its productive base is shrinking. That can't go on indefinitely, of course, but if national accountants did not monitor asset stocks, no one would know. That points to the significance of the Brundtland Report. In defining the notion of sustainable development, the Report hinted that economic opportunities are embedded in stocks of capital assets, not in flows of incomes.

It is worth exploring further the ways in which the Report pointed in the right direction. As capital stocks are an economy's productive base, the set of options available on any date depends on the portfolio of assets the economy holds at that time. Just as acquiring human capital (health, education, skills, aptitude, or character) enables people to expand their life opportunities, enlarging an economy's portfolio of capital stocks creates greater opportunities for the economy. The Brundtland criterion for sustainable development can thus be interpreted as a developmental path along which an economy's portfolio of assets expands over time.

But assets differ, which means the mix of assets in an economy's portfolio matters—a mere head count won't do. To expand a nation's economic opportunities, decision-makers may have to disinvest from some assets and invest in other more productive assets.[2] Moreover, opportunities themselves differ in their

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[2] The commonality of purpose between ecological economics and financial economics is self-evident.

attractiveness. So, the Brundtland criterion requires an ethical dimension, which captures the *social worth* of assets, that is, their 'shadow prices'.[3] This it did not provide; it was left to others to fill those large blanks.

Recall that the 'shadow price' of a good or service is the contribution that an additional unit of it would make to social well-being, other things equal. Estimating shadow prices, therefore, involves counterfactual reasoning. Because the economy moves through time, social well-being at any point of time includes not only the well-being of the people present today, but that of future people as well. We can call our temporal conception of social well-being 'well-being across the generations'. It should be noted that well-being across generations is not a Platonic ideal but represents an an evaluative judgement of the value of goods and services and the economy's future prospects from a public viewpoint. It should also be noted that no two people would ever agree on shadow prices, for their ethical perspectives would inevitably differ. Ecological economics furnishes us with the tools to whittle down our disagreements on such evaluative judgements, but it cannot eliminate disagreements entirely.

Shadow prices combine the possible and the desirable. The 'possible' is reflected in the economic projections on which decision-makers base their price estimates.[4] The 'desirable' appears in this conception of well-being across generations, which we deploy to reflect our values when assuming the public viewpoint. And the public viewpoint can be adopted by a person regardless of the character of the society they study. Shadow prices are thus 'all things considered' judgements.

The chancellor's invitation therefore offered me an opportunity to prepare a report that puts the ideas in environmental and resource economics together and extend them to a larger concern, perhaps the largest there is for us social scientists—how we should read our place

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3 Shadow prices are also called 'accounting prices'.

4 There is no presumption that the economy is well-managed; shadow prices are as relevant in well-ordered societies as in dysfunctional ones. For elaboration on the latter point, see Dasgupta, Marglin, and Sen (1972).

in the world as we go about our daily lives. Biodiversity, of which we are ourselves a part, would appear seamlessly in the study because it is an integral part of Nature. No doubt preparing such a report was a tall order, but my Treasury team, drawn from government departments and non-government organizations, told me they expected nothing less.

As I had been working closely for some years with ecologists, I wanted to base my report on two disciplines—ecology and economics. In any case, they have much to say to each other, starting with the shared prefix 'eco-', whose root is the Greek '*oikos*', meaning house or habitat. But 'house' or 'habitat' could refer to a household, community, district, nation, region, or even the whole world. That is why the report I submitted to the chancellor in February 2021, *The Economics of Biodiversity: The Dasgupta Review* (Dasgupta 2021), has a wide reach, ranging from the very small to the very large, both spatially and temporally.

However, differences in the way people and their communities fashion their lives tell us that they do not all experience the degradation of Nature in the same way. Food, potable water, clothing, warmth, a roof over one's head, clean air, a sense of belonging, participating with others in one's community, and a reason for hope are no doubt universal needs; but the emphasis people place on the goods and services Nature supplies differs widely. For farmers in sub-Saharan Africa, the central concern could be declining water sources and increasing rainfall variability against the backdrop of global climate change; for Indigenous populations in Amazonia, it may be eviction, not just from their physical homes, but from their spiritual home too; for inhabitants of shanty towns everywhere, the greatest worry may be the infections they are exposed from open sewers; for suburban households in the UK, it may be the absence of bees and butterflies in the garden; for residents of megacities, it could be the poisonous air they breathe; for the multinational company, it may be worries about supply chains, as disruptions to the biosphere make older sources of primary products unreliable and investments generally more risky; for governments in some places, it may be the call by citizens, even children, to stem global climate change; and for people everywhere today, it may be the ways in which those varied experiences combine and give rise to environmental problems that affect us all, not least the COVID-19 pandemic and other emerging infectious diseases, of which changing land use and exploitation of species are major drivers. No, the degradation of Nature is not experienced in the same way by everyone. That is why the final report, the *Dasgupta Review*, which I submitted to the UK Treasury in 2021, was 601 pages long, with text interspersed with boxes, annexes, and starred chapters containing analysis conducted in the language of mathematics (Dasgupta 2021).

The *Review* (Dasgupta 2021) was built entirely on what seems to me to be the central empirical finding on the character of the global economy, which is that the demands we are making today on Nature's goods and services far exceed her ability to supply them on a sustainable basis. The difference between the two, a gap of over 70% today (see, next section), is a measure of human ecological overreach. That 70% figure is what people refer to these days when they say we need 1.7 Earths to meet our current global demand for Nature's goods and services on a sustainable basis. The proximate determinants of the two sides of the demand and sustainable supply gap are, on the demand side, global GDP and the aggregate quantity of Nature's goods and services that are drawn to produce that GDP, and on the supply side, Nature's regeneration rate. The *Review* (Dasgupta 2021) uses economics to uncover the factors that explain those determinants' relationship to one another over time and what options humanity has to close the gap. In the remainder of this paper, I flesh out these ideas.

5. THE ECONOMICS OF BIODIVERSITY AS PORTFOLIO ANALYSIS

Whether as farmers or fishers, foresters or miners, households or companies, governments or communities, we manage the assets to which we have access in line with our motivations and as best as we can. But the best each of us can achieve with our portfolios may nevertheless result in a massive collective failure to manage the global portfolio of assets. The analogy of a crowd of people trying to keep their balance on a hanging bridge and bringing it crashing down speaks to that possibility.

How would you know whether you are managing your portfolio of assets well? What rule would you follow? For simplicity of exposition, imagine there is a perfect market for every commodity. You know the price of every commodity; the market informs you how the relative prices of goods and services will change over time. You have a certain amount of funds (your wealth) that you can allocate between current consumption and savings, knowing that putting your savings into stocks, bank deposits, and government bonds represents future consumption. So, by dividing your available wealth into current consumption and savings, you are trying to balance current and future consumption. Once you do that (and it's not a trivial problem to solve, as it involves trading your desire for consumption today against the future consumption stream you would enjoy if you added to your savings),[5] the next step is to determine the right investment portfolio for your savings.

Imagine that you have set aside W rupees as savings. You now want to distribute the W rupees between a portfolio of stocks and bonds, plus a savings account in the bank. The return on holding stocks and bonds is expected to be ϱ per year. On the other hand, the bank offers you a fixed interest rate of, say, r a year. You would be indifferent between holding your savings in the bank deposit versus investing in stocks and bonds if the two rates were equal—that is, if r equalled ϱ. But ϱ is the sum of the yields offered by stocks and bonds at the end of the year and the capital gains (or losses) they enjoy. So, that's the condition the mixed portfolio must satisfy: Hold only those assets that offer you the maximum returns. If that maximum is r, you will hold a mixed portfolio: a certain portion in the bank with the rest in stocks and bonds. You will, at the margin, be indifferent between holding any of the assets in your efficient portfolio, because they all offer you the same return.

Let us now use this reasoning to consider the global economy today. We begin by assuming that a public agency is efficiently managing a portfolio consisting of a pair of assets. We then check whether the two assets offer the same rate of return. If we find they don't, we

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[5] A huge body of technical literature on the concept of optimum savings, initiated by Ramsey (1928), speaks to this set of concerns.

conclude that our assumption was wrong and that the agency is not managing its portfolio efficiently.

Economists have estimated that the long-run rate of return (rent or dividend) on housing and equities in the US is around 5% a year. If we choose that to be the unit of accounting (i.e., the *numeraire*), then 5% should be regarded as its yield. Let us now contrast that with an example of yield from an item of natural capital. In an exceptional paper, Markandya and Murty (2004) conducted a social cost/benefit analysis of an action plan of the Government of India that outlined measures to raise the quality of the Ganges river water to a standard fit for bathing. The Ganges is one of the most polluted rivers in the world. The authors administered questionnaires to people living in the Ganges basin to estimate their 'willingness to pay' for a cleaner river and so estimated the annual social benefits that could be realized by the action plan. The investment outlay and recurring costs were taken from the planning documents. Using that data, the authors estimated the project's rate of return to be around 15%.

Consider, say, a public agency that holds shares in US housing and equities and has an interest in how cleanliness of the Ganges. The agency, therefore, can be thought to be holding both these stocks. If the portfolio were efficient, the implicit value of Ganges water should *decline* relative to public income by some 10% a year (15% less 5%).

However, evidence shows that rapid urban development in the Ganges basin has been worsening the quality of the river, even as per capita income in the region has been rising. Taken together, this implies that the Ganges has become *scarcer* relative to produced capital, not more abundant (in fact, the Ganges Action Plan was soon abandoned, so that the river's water quality has continued to deteriorate). That is a rough-and-ready way to establish the imbalance in economic development: The asset portfolio in question is inefficient.

This familiar piece of reasoning in portfolio analysis gives us a language to discuss what has gone so drastically wrong in our management of the biosphere. The global economy, never mind the myriads of local economies, has mismanaged the portfolio of produced capital, human capital, and natural capital by *divesting* heavily from the latter in favour of the former pair. This is confirmed by studying global demand for Nature's goods and services and comparing it with Nature's ability to meet that demand on a sustainable basis.

6. THE HUMAN DEMAND FOR NATURE'S GOODS AND SERVICES

I have discussed ecosystems and the goods and services they produce with specific examples, but can we also classify them to cover the entire biosphere? In the discussion that follows, I deploy the Common International Classification of Ecosystem Services (CICES) defined by the European Union, which builds on the pioneering work of the Millennium Ecosystem Assessment (MEA 2005) to offer a three-way classification of ecosystem goods and services.

a. **Provisioning goods** are those we harvest or extract from ecosystems. Their regeneration is a flow (measured in additional tonnes of organic material mass per year), whereas the goods themselves are stocks (measured in tonnes of biomass: period). Provisioning goods include food, fresh water, timber, and fuel (dung, wood, twigs, and leaves), fibre (grasses, cotton, wool, and silk), soil and gravel as building materials, biochemicals and pharmaceuticals (medicines and food additives), genetic resources (genes and genetic information used for plant breeding and biotechnology), and ornamental resources (skins, shells, stones, and flowers).

b. **Maintenance and regulating services** maintain and regulate ecosystem processes, including maintaining the gaseous composition of the atmosphere, regulating local and global climate (temperature, precipitation, winds, and currents), controlling erosion (soil retention and and preventing landslides), regulating the flow of water (the timing and magnitude of runoff, flooding, and aquifer recharge), purifying water and decomposing waste, regulating diseases (controlling the abundance of human pathogens such as cholera and disease vectors such as mosquitoes, as well as controlling crop/livestock pests and diseases, pollinating plants, and offering protection against storms (forests and woodlands on land, mangroves and coral reefs on coasts), recycling nutrients, and maintaining the ability of primary producers to photosynthesize.

c. Cultural services offer non-material benefits, including Nature tourism, spiritual experiences, and the identification of ecosystems with religious values and sacred spaces. (It is perhaps more appropriate to trace these experiences and values to Nature rather than ecosystems, however, because the latter is a term of recent origin.) The diversity of life has, in part, shaped our diversity of cultures. Moreover, various systems of thought attach spiritual and religious significance to flora and fauna. People also find aesthetic value in Nature, which finds expression in private gardens and public parks, in protected areas, and in a large ecotourism industry. Ecosystems influence social relationships—social capital in coastal fishing villages takes a different form from that in nomadic herding and agricultural societies—and local ecosystems also offer people a sense of place and a cultural landscape.

Although cultural services are supremely important to humankind, the first two are more fundamental, for they are independent of human presence. Provisioning goods and maintaining/regulating services evolved and formed the character of the biosphere even before hominids, let alone humans, existed. That is why we focus on them here.

Provisioning goods are Nature's 'produce'; their regeneration over a period is Nature's 'yield'. Through human ingenuity, these provisioning goods are transformed into the final products that, when aggregated using market prices, read as GDP.

In contrast, maintenance and regulating services act upon stocks of natural capital and replenish them. By replenishment or regeneration, I mean net regeneration: 'births' minus 'deaths'. In a fishery, for example, there is renewal even when births equal deaths, that is, when net regeneration is zero. Fungi are involved in decomposing dead material and our waste products, enabling ecosystems to regenerate; birds and insects pollinate, helping to create new life; and so on. These processes involve energy flows and material transfers, which contribute to the production of maintenance and regulating services. There is mutual feedback between provisioning goods and maintenance and regulating services.

There is a further distinction between them. Provisioning goods are specific to ecosystems. In contrast, maintenance and regulating services are partly specific to ecosystems and partly global. The fishes we catch are specific to the lake from which we catch them, while the decomposition of fallen leaves is largely facilitated on-site by local bacteria and fungi, but climate regulation involves the movement of energy and materials across the globe. The difference between *drawing upon* Nature for provisioning goods and *depending on* Nature for maintenance and regulating services is all-important here. As the processes that furnish us with Nature's maintenance and regulating services are, for the most part, silent and invisible, their significance continues to be underestimated as we go about our daily lives.

In the MEA (2005) framing above, biodiversity is seen as underpinning all four types of ecosystem services, but is (rightly) not considered an ecosystem service in itself.

7. ECOLOGICAL FOOTPRINT

A society's 'ecological footprint' is the aggregate quantity of provisioning goods it draws from the biosphere in a given period. What is drawn is mostly visible and recordable. It is the society's *direct demands* on Nature in that period. The corresponding *indirect demands*—we can also call them 'needs'—are for Nature's maintenance and regulating services. Humanity would be overreaching in provisioning goods if the global ecological footprint exceeded the biosphere's regeneration capacity. We would not know of the overreach immediately, though; we would recognize it only when ecosystems begin to show signs of fatigue (i.e., a decline in maintenance and regulating services), requiring interventions to compensate.

A community's ecological footprint is in overreach if it exceeds the ecosystem's regeneration capacity (i.e., the yield) for the provisioning goods it withdraws. If we are to formulate policies that eliminate such overreach, we need a way to measure it—one that is built on the community's actions. The trick is to find quantifiable measures for those actions. To do that, we must consider the global economy.

We would ideally want to compare the demands the global economy makes on each category of provisioning goods (food, water, fibres, timber, and so on) with the regeneration rates of the ecosystems that supply them. It could be that the global economy overreaches for some goods but not others. Here, we suppose for simplicity that we can aggregate our demands into a scalar measure. It is possible to do that by attaching weights to the demands we make across all categories of provisioning goods and adding them together. That would give us a combined measure of the demand humanity makes on the biosphere's provisioning goods. The weights are the familiar 'shadow prices'.[6] We denote the combined measure of demand (i.e., the global ecological footprint) as D. In a classic paper, Ehrlich and Holdren (1971) read D as being humanity's 'impact' on the biosphere.

8. IMPACT INEQUALITY

The drivers of our ecological footprint are our activities. The common measure of humanity's activities is the global GDP, which we write as Y. Y is the market value of the final goods and services produced in a period (a year), expressed, say, in international dollars. But as the goods and services that are drawn from Nature to produce the final goods in the human economy do not have the dimension of international dollars, we need a conversion factor from dollars to the combined measure of provisioning goods the global economy draws on to produce its GDP. Let α denote the ratio of GDP to the combined measure of provisioning goods that the economy uses to produce GDP. Thus, α is the efficiency with which provisioning goods are drawn upon to produce GDP. Humanity's ecological footprint is therefore the global GDP divided by the efficiency with which Nature's goods and services are drawn upon to produce it, that is, Y/α. It will prove useful to remember that the smaller the combined measure of Nature's goods and services required to produce the global GDP, the larger is the value of α.

We can unpick the global ecological footprint further. Notice that the global GDP is, by definition, the product of global population (N) and the per capita global GDP (y). The global ecological footprint in

[6] Wackernagel and Beyers (2019) have devised an ingenious method for estimating the combined demand for provisioning goods in a given period.

a period is thus the global population multiplied by the per capita global GDP (*Ny*) and divided by the efficiency with which provisioning goods are drawn upon to produce GDP (α). That gives us the combined global demand for provisioning goods (*D*), that is, the global ecological footprint.

We have now identified the drivers of humanity's footprint. Other things being equal, the larger the global population, the larger the footprint in that period. Similarly, the larger the per capita GDP, the larger the footprint. It is also clear that the smaller the quantity of provisioning goods that the global economy draws on to produce GDP—which is to say, the larger α is—the smaller the footprint. In other words, the more efficient humanity is at converting Nature's provisioning goods into the products that add up to the global GDP, the smaller its footprint. Ehrlich and Holdren (1971) interpreted the efficiency with which the global economy draws upon provisioning goods to produce the GDP (α) as an expression of the technology that is deployed to produce the GDP, but institutions should also be included, because they too have an influence. Provisioning goods have been systematically undervalued everywhere, meaning that the global economy uses more provisioning goods to produce output than it should. That is another way of saying that the quantity of provisioning goods that the global economy draws on to produce GDP is larger than what it should be, or in other words, α is smaller than what it could be.

We now turn to the supply side. By supply, we mean Nature's net output of provisioning goods or, in other words, her 'yield'. We could interpret yield as the regeneration rate of the stock of Earth's natural capital. But in line with how we have constructed global demand, we may assign numerical weights and compute a weighted sum of ecosystem regeneration rates. The weights, which are numerical quantities, are needed because different ecosystems produce different sets of provisioning goods. The procedure is rather like calculating the market value of a shopping basket, in which market prices (the weights) aggregate a variety of goods under a single numerical measure of value. The factors that determine the regeneration rate of an ecosystem are the ecosystem's size and its productivity. The weighted sum of the regeneration rates of all ecosystems would then represent a combined measure of the biosphere's regeneration rate, which we can call *G*. Next, I show a way to estimate the weights.

Globally, there is an ecological overreach in a given period if the global ecological footprint exceeds Nature's combined regeneration rate. When that happens, the biosphere's productivity diminishes, which means the supply of provisioning goods is lower in the following period.[7] Formally, there is a global ecological overreach if,

$$Ny/\alpha > G \tag{1}$$

Wackernagel and Beyers (2019) reported that expression (1) holds for the global economy—an expression we may call the 'impact inequality'.[8] The authors also provided an estimate of the gap, by reporting that the ratio of the left-hand side of the inequality to the right-hand side is currently approximately 1.7.

Notice that the impact inequality is only a snapshot of the global economy. It is an accounting statement on the state of the biosphere in a given period and says nothing about the mutual interplay of global population, per capita global GDP, and the quantity of provisioning goods that the global economy draws on to produce that GDP, or their effect on the future values of the combined regeneration rates. To study the interactions among the four variables requires a dynamic socio-ecological model.[9]

Impact inequality gives us a way to identify policy levers. For example, health and education policies can influence the future values of the global population (N), fiscal policies can affect global per capita GDP, (y) and institutional reforms and investment in new technologies can influence the quantity of provisioning goods that the global economy draws on to produce GDP (the efficiency parameter α). Conservation measures and what is commonly known

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[7] To think that global demand (i.e., the global ecological footprint) could exceed the combined regeneration rate indefinitely is to presume the biosphere to be of infinite size.

[8] I have defined the impact inequality for the global economy. One can, of course, define corresponding relationships between demand and sustainable supply of provisioning goods for smaller economic units. It will prove useful to remember from the impact inequality that, other things being equal, the larger the α, the smaller is the global ecological footprint.

[9] Prototypes of such a model have been constructed in Dasgupta (2021, 2024).

as 'green investments' increase the future values of Nature's combined regeneration rate (*G*). Projecting movements in our global footprint (*D*) and combined regeneration rates of provisioning goods (*G*) over time should now be at the heart of discussions on sustainable development.[10]

9. MEASURING GLOBAL DEMAND AND SUSTAINABLE SUPPLY

How might one come up with the figure to encapsulate a combined measure of provisioning goods? One way to do that would be to follow a practice used in the US, where pastures are sometimes measured in 'cow–calf acres', which is the number of cow–calf pairs that can be maintained on one acre. Obviously, the number of cow–calves a farm can maintain depends on the size and productivity of the pasture. In an ingenious set of exercises, Wackernagel and his scientific collaborators (Wackernagel *et al.* 2019) deployed the same idea to estimate demand (*D*) and combined regeneration rate (*G*) for the global economy and for individual countries too. The authors estimated the quantity of provisioning goods humanity draws from the biosphere in a period by calculating the area of land and sea across different categories of ecosystems (including agricultural land, plantations, wetlands, fisheries, marshes, oceans, and forests) needed to yield the global GDP in dollars, while leaving space for other life forms to provide pollination, seed dispersal, fertilization, waste decomposition, and other maintenance and regulating services that would be needed to simultaneously replenish the global stock of ecosystems. In short, the idea is to measure the land–sea area that would support the global GDP indefinitely, which the authors call the Earth's 'bio-capacity'. For example, the land–sea area required to meet our demand for natural fibres in a given period without compromising the ability of the biosphere to replenish the quantity of

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[10] The broader definition of sustainable development, as we noted earlier, is an economic path along which wealth increases over time. That's because well-being across the generations moves in the same away as wealth: the former increases over time if and only if the latter does. For a formal statement of the equivalence between wealth and well-being and its proof, see Dasgupta and Mäler (2000).

natural fibres that have been harvested in that period is taken to be the Earth's bio-capacity for natural fibres. Similarly, the area occupied by primary producers (forests, marshes, and grasslands) needed to recycle current CO_2 emissions is the Earth's bio-capacity for carbon regulation. The same reasoning is deployed to calculate demand for other provisioning goods as well.

However, various ecosystems differ in their ability to provide the same service. Marshes, for example, sequester 8–10 times the carbon that temperate forests do. In estimating the Earth's bio-capacity for carbon recycling, Wackernagel *et al.* (2019) therefore awarded 1 sq km of marshland a weightage of 8–10, as against a weightage of 1 for 1 sq km of temperate forest. They did the same for a wide range of other maintenance and regulating services. The demand of the global economy for provisioning goods in a period is, then, a weighted sum of land–sea areas that would supply sufficient maintenance and regulating services in that same period to replenish the stocks of provisioning goods that have been depleted. This is another way to express global demand (*D*)—the left-hand side of the impact inequality.

In contrast, Nature's combined regeneration rate (*G*) represents the right-hand side of the impact inequality, which is estimated from the prevailing land–sea area worldwide. As mentioned previously, Wackernagel *et al.* (2019) reported that global demand has been increasing rapidly in recent decades and that the ratio of global demand to the combined regeneration rate (*D* to *G*) today is about 1.7. In other words, we need 1.7 Earths to meet humanity's current demands on a sustainable basis.

The authors also found from the data that the global demand was lower than the combined regeneration rate (*G*) as recently as the 1960s, having crossed the equality mark only in the early 1970s. It seems that only a few decades ago, the world economy was not overly large relative to the biosphere. Humanity lived on < 1 Earth and we shared it with greater numbers of other creatures; but even at that time, we had been closing in on other life forms. We have now closed in on them and are increasingly doing so.

10. IMPOSSIBILITY OF INDEFINITE GDP GROWTH

As the biosphere is finite, it's supply of provisioning goods must be bounded. That means the combined regeneration rate (*G*) is bounded above. What does this imply for the 'unending' GDP growth? We could imagine that to be a possible future by insisting that, just as there is no limit to human imagination, there is no limit to how any given quantity of provisioning goods can be converted into global GDP through technological and institutional improvements. So long as the global GDP does not grow at a faster rate than the rate at which the efficiency with which the combined measure of provisioning goods required to produce the GDP (α) grows (the left-hand side of the impact inequality), it can be kept within Nature's bounds, being no greater than the combined regeneration rate.

Thus, to take the possibility of unending GDP growth seriously would require of us to imagine that if GDP were to grow indefinitely, the efficiency with which the combined measure of provisioning goods required to produce the GDP (α) grows would also have to be indefinite, and at least grow at the same rate as the GDP—otherwise, the left-hand side of the impact inequality would not remain within Nature's bounds. In turn, this requires us to imagine that, no matter how gigantic the global economy becomes, investments in scientific and technological projects aimed at *further* lowering global demand for provisioning goods needed to produce a unit of GDP would become ever smaller. However, that would require us to imagine that if the global GDP were to become larger, we would attain greater freedom from our dependence on the biosphere. It is in this way that economic policies based on the idea of perpetual GDP growth presume that the human economy is *external* to Nature, not *embedded* in Nature. In this context, our embeddedness in Nature amounts to insisting that no matter how much we invest in science and technology or improve our institutions, the quantity of provisioning goods required to produce the GDP cannot be reduced beyond a point, which is to say that the efficiency with which provisioning goods can be converted into GDP (α) cannot be increased beyond a point.

Ardent advocates of GDP growth have been known to retort that they neither foresee nor advocate indefinite growth, but growth only over the next 100 years, say. For them, the 'long run' is not an indefinite future, but a sizeable future. But that explanation runs into the problem of the global economy already being in a deficit, given the 1.7 ratio of demand to supply. Growing as much as the human economy has over the past 70 years, we have brought critical ecosystems close to their breaking points. So, whatever 'sustainable development' might mean, it must at a minimum eliminate our ecological overreach.

The most urgent task facing humanity today is to find ways to bring about an equality between the global demand for Nature's provisioning goods and her ability to meet humanity's demand on a sustained manner, in temporal terms (that is, close the impact inequality). That would require lowering global demand for provisioning goods (*D*) and enabling Nature to raise her combined regeneration rate (*G*), thus closing the gap in inequality (1). The long run is beyond our grasp. We should now be concerned with now and the near future.

11. EVIDENCE IS MODEL-BASED

The analysis I have sketched in this paper raises an awkward question: Economic commentators rightly demand that public policies should be evidence-based, but they usually overlook that 'evidence' is of no use if it is obtained from a misleading conception of the human condition, for faulty models produce spurious evidence. Systems of thought that do not acknowledge humanity's embeddedness in Nature will mislead us if used to project present or future possibilities. The findings of ecologists and Earth scientists have increasingly demonstrated that such systems of thought mislead so hugely that policies based on them not only endanger future generations but also damage the lives of the world's poor in the here and now. In this paper, I have shown that the enormously large and influential bodies of literature on growth and development economics and the economics of poverty, focusing as they largely do on GDP and its distribution among goods and people while excluding Nature, remain impoverished on this count. It reads as an elaborate exercise in collective solipsism.

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REFERENCES

Brundtland Commission. 1987. *Our Common Future: Report of the World Commission on Environment and Development*. Oxford University Press.

Dasgupta, Partha, and Karl-Göran Mäler. 2000. "Net National Product, Wealth, and Social Well-Being." *Environment and Development Economics* 5 (1): 69–93. https://doi.org/10.1017/S1355770X00000061.

Dasgupta, Partha, Stephen A Marglin, and Amartya Sen. 1972. *Guidelines for Project Evaluation in Developing Countries*. United Nations. https://downloads.unido.org/ot/46/88/4688269/double%20-%20Guidelines%20for%20Project%20Evaluation.pdf.

Dasgupta, Partha, T C A Anant, K Basu, K Chopra, N Desai, H Gundimeda, V Kelkar, R Kolli, K Parikh, P Sen, P Shyamsundar, E Somanathan, and K Sundaram. 2013. *Green National Accounts in India: A Framework*. Report by an Expert Group convened by the National Statistical Organisation, Ministry of Statistics and Programme Implementation, Government of India. https://www.mospi.gov.in/sites/default/files/publication_reports/Green_National_Accouts_in_India_1may13.pdf

Dasgupta, Partha. 2021. *The Economics of Biodiversity: The Dasgupta Review*. Her Majesty's Treasury. https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review.

Dasgupta, Partha. 2024. *The Economics of Biodiversity: The Dasgupta Review*. Cambridge University Press. https://doi.org/10.1017/9781009494359.

Dasgupta, Partha. 2025. *On Natural Capital: The Value of the World Around Us*. Witness, Penguin.

Dasgupta, Partha. 2026. *On Natural Capital: The Value of the World Around Us*. HarperCollins.

Ehrlich, Paul R, and John P Holdren. 1971. "Impact of Population Growth." *Science* 171 (3977): 1212–17. https://doi.org/10.1126/science.171.3977.1212.

Mäler, Karl-Göran. 1974. *Environmental Economics: A Theoretical Inquiry*. Johns Hopkins University Press.

Markandya, A, and M N Murty. 2004. "Cost–Benefit Analysis of Cleaning the Ganges: Some Emerging Environment and Development Issues." *Environment and Development Economics* 9 (1): 61–81. https://doi.org/10.1017/S1355770X03001013.

Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and Human Well-Being: Synthesis.* Island Press.

Ramsey, F P. 1928. "A Mathematical Theory of Saving." *Economic Journal* 38 (152): 543–59. https://doi.org/10.2307/2224098.

Rockström, Johan, Will Steffen, Kevin Noone, Åsa Persson, F. Stuart III Chapin, Eric Lambin, Timothy M. Lenton, Marten Scheffer, Carl Folke, Hans Joachim Schellnhuber, Björn Nykvist, Cynthia A. de Wit, Terry Huges, Sander van der Leeuw, Henning Rodhe, Sverker Sörlin, Peter K. Snyder, Robert Costanza, Uno Svedin, Malin Falkenmark, Louise Karlberg, Robert W. Correll, Victoria J. Fabry, James Hansen, Brian Walker, Diana Liverman, Katherine Richardson, Paul Crutzen, and Jonathan Foley. 2009. "Planetary Boundaries: Exploring the Safe Operating Space for Humanity". *Ecology and Society* 14 (2): 32. http://www.ecologyandsociety.org/vol14/iss2/art32

Steffen, Will, Katherine Richardson, Johan Rockström,Sarah E. Cornell, Ingo Fetzer, Elena M. Bennett, Reinette Biggs, Stephen R. Carpenter, Wim De Vries, Cynthia A. de Wit, Carl Folke, Dieter Garten, Jens Heinke, Georgina M. Mace, Linn M. Persson, Veerabhadran Ramanathan, Belinda Reyers, and Sverker Sörlin. 2015. "Planetary Boundaries: Guiding Human Development on a Changing Planet". *Science* 347 (6223): 1259855. https://doi.org/10.1126/science.1259855

Wackernagel, Mathis, and Bert Beyers. 2019. *Ecological Footprint: Managing our Biocapacity Budget.* New Society Publishers.