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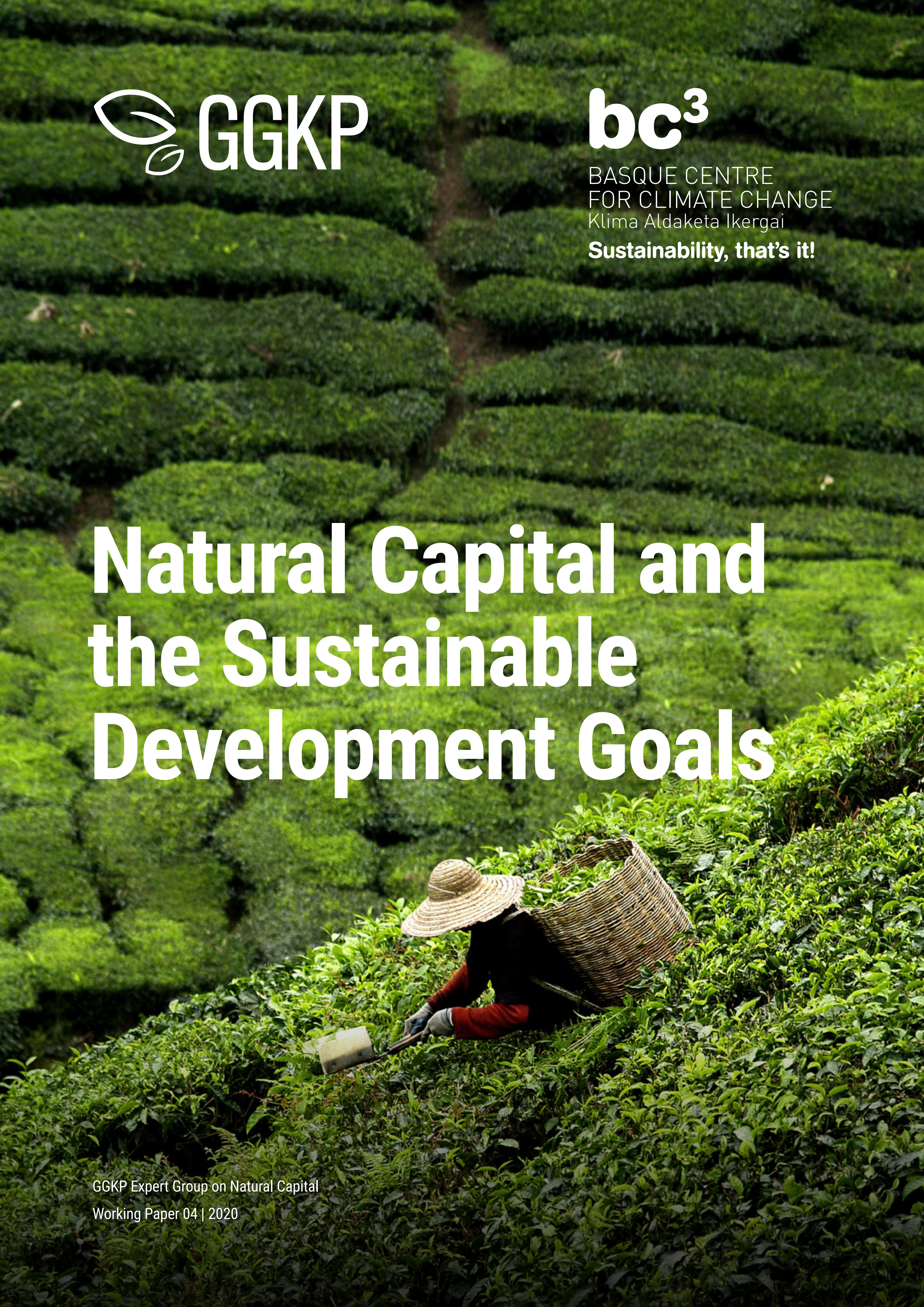
Klima Aldaketa Ikergai
Sustainability, that's it!



Natural Capital and the Sustainable Development Goals

GGKP Expert Group on Natural Capital

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Anil Markandya

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

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

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

To clarify this gap and identify pathways to address it, the Expert Group, with support from the GGKP Secretariat, commissioned the Basque Centre for Climate Change to prepare this report. This publication was produced by Anil Markandya (Basque Centre for Climate Change) with Expert Group guidance.

The Expert Group was led by Co-Chairs Paul Ekins (Professor at University College London and Director of the Institute for Sustainable Resources) and Joe Grice (Chairman of the United Kingdom Office for National Statistics Economic Experts).

The Expert Group is composed of members from various organizations, including Charles Akol (United Nations Economic Commission for Africa), SoEun Ahn (Korea Environment Institute), Alessandra Alfieri (United Nations Statistics Division), Carter Brandon (World Resources Institute), Raouf Dabbas (Jordan Friends of Environment Society), Gitika Goswami (Development Alternatives), Salman Hussain (UNEP The Economics of Ecosystems and Biodiversity), Katia Karousakis (OECD), Pushpam Kumar (UNEP), Glenn-Marie Lange (World Bank), Markus Lehmann (Convention on Biological Diversity), Anil Markandya (Basque Centre for Climate Change), Geoff McCarney (Smart Prosperity Institute), Edwin Muchapondwa (Environment for Development Initiative), Rosimeiry Portela (Conservation International), Mary Ruckelshaus (Natural Capital Project), Oyun Sanjaasuren (Green Climate Fund), Mark Schauer (Economics of Land Degradation (ELD) Initiative/Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)), Tim Scott (United Nations Development Programme), Juha Siikamäki (International Union for Conservation of Nature), Kevin Urama (African Development Bank), Annawati van Paddenburg (GGGI) and James Vause (UNEP-World Conservation Monitoring Centre).

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EXECUTIVE SUMMARY

The paper reports the results of an initial investigation of the link between the UN Sustainable Development Goals (SDGs) and the natural capital requirements they embody and provides initial estimates of the "natural capital gap". It also sets out how a natural capital approach may be used to evaluate projects where the aim is to restore degraded areas and enhance the ecosystem services they provide.

Attaining a number of the SDGs depends on increasing the stock of natural capital. The difference between the level of such capital now and the amount that will need to be present to meet the SDGs is called the natural capital gap. The paper elaborates on the kinds of natural capital needed for those SDGs where it has an important role. These include goals related to hunger and food security (SDG 2), sustainable water management (SDG 6), safe, resilient and sustainable cities (SDG 11), ensuring sustainable consumption and production patterns (SDG 12), meeting the Paris Agreement on climate change (SDG 13), conserving marine ecosystems (SDG 14) and conserving terrestrial ecosystems (SDG 15).

In each case, it reports the amount of additional natural capital needed to meet the SDGs given the expected path of the global economy. Estimates are presented as a range due to the substantial uncertainties involved. Not all SDGs could be tracked in terms of a monetary value of natural capital. Where this is not possible, qualitative indicators are proposed that complement the information on the monetary values.

The sum of the natural capital gap is estimated at between \$31.9 and \$86.9 trillion, with the largest uncertainties arising from the value of remediating land, reducing forest loss and reducing loss of wetlands. In relative terms, the largest share is related to land remediation. One can compare this natural capital gap with the estimate of the current stock of natural capital as estimated by the World Bank, which puts the value at about \$105 trillion globally. This analysis suggests that meeting these SDGs could enhance that stock by between 30 per cent and 83 per cent.

The paper goes on to discuss how to use a natural capital approach to appraise programmes aimed at restoring natural capital. This could be used in parallel with the more conventional cost-benefit approach, but with a focus on looking at different ways in which a given increase in natural capital can be achieved.

The next step in the work is to make a more detailed analysis of the gap at the national level and firm up some of the provisional figures used here. The gaps can then be compared with the costs of eliminating them in the most cost-effective manner. This will also provide an indication of where scarce resources should be used to eliminate different components of the natural capital gap.

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LIST OF ACRONYMS

BAU	Business as usual
CBA	Cost-benefit analysis
CBD	Convention on Biological Diversity
CEA	Cost-effectiveness analysis
CRED	Centre for Research on the Epidemiology of Disasters
DALYs	Disability Adjusted Life Years
ELD	Economics of Land Degradation Initiative of GIZ
EM-DAT	Emergency Events Database
ESS	Ecosystem Services
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
GHGs	Greenhouse gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GLADA	Global Assessment of Land Degradation and Improvement
HANPP	Human Appropriation of Net Primary Productivity
IAM	Integrated Assessment Model
IRP	International Resources Panel
LB	Lower bound
MCA	Multi-criteria analysis
OECD	Organisation for Economic Co-operation and Development
$PM_{2.5}$	Particulate matter with a diameter of 2.5 μm or less
PPP	Purchasing power parity
SCC	Social cost of carbon
SDGs	Sustainable Development Goals
TEEB	The Economics of Ecosystems and Biodiversity
TWA	Total water availability
TWW	Total water withdrawal
UB	Upper bound
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization
WRI	World Resources Institute

1. INTRODUCTION AND STRUCTURE OF THE PAPER

Natural capital has a major role in places where its deterioration has caused, and is likely to cause, a problem in meeting some key development goals, such as those defined by the UN Sustainable Development Goals (SDGs). Focusing on these capital needs gets us away from the measurement of natural capital at the national level, where a small estimated value has caused some concern, and concentrates on where the amounts of such capital matter most. It also allows natural capital needs to be defined relative to target values of the SDGs, which in turn can be linked to threshold levels of natural capital.

The natural capital approach can also be useful in evaluating projects where the aim is an improvement in ecosystem services. Such projects involve the use of physical capital and human resources to reverse the deterioration of ecosystems and are commonly evaluated through a cost-benefit framework that looks at benefits in terms of flows of services gained against costs in terms of the opportunity cost of human and physical capital deployed. Instead, it is argued that a natural capital approach can provide a parallel set of accounts with a "capitals" approach, where the gain in natural capital is evaluated, possibly relative to threshold values of that form of capital, and compared against uses of other forms of capital. This has the advantage of providing an estimate of the cost of increasing the stock of natural capital to meet a given SDG target and allowing the authorities to choose between alternative programmes that remediate a given stock of natural capital, such as degraded land.

THIS SCOPING PAPER:

- Reports the results of an initial investigation of the link between the SDGs and the natural capital requirements they embody and provides initial estimates of the natural capital gap.
- Sets out how a natural capitals approach may be used to evaluate projects where the aim is to restore degraded areas and enhance the ecosystem services they provide.

2. LINKS BETWEEN THE SDGS AND THEIR NATURAL CAPITAL REQUIREMENTS

The dependence of the SDGs to the biosphere was demonstrated by the Stockholm Resilience Centre in the iconic figure of the "wedding cake" (Figure 1). The bottom layer of the cake is the biosphere onto which societies and economies are embedded as further layers. The SDGs track progress on different aspects of each of the layers, but ultimately all of them draw on, and ultimately depend on, progress on the maintenance of a healthy biosphere that is tracked through SDGs 6 (clean water and sanitation), 13 (climate action), 14 (life below water) and 15 (life on land).

This biosphere can be viewed as the planet natural capital, whose value is determined by the flow of services it provides to the economies and societies in the upper layers.

In this paper, we aim to establish the links between specific SDG targets and the increases in natural capital they represent. Altogether there are 17 SDGs and 169 associated indicators (UN, 2016). Although natural capital has some relevance to the attainment of all the goals, nine of them have strong and direct links to the stock of such capital. These are:[1]

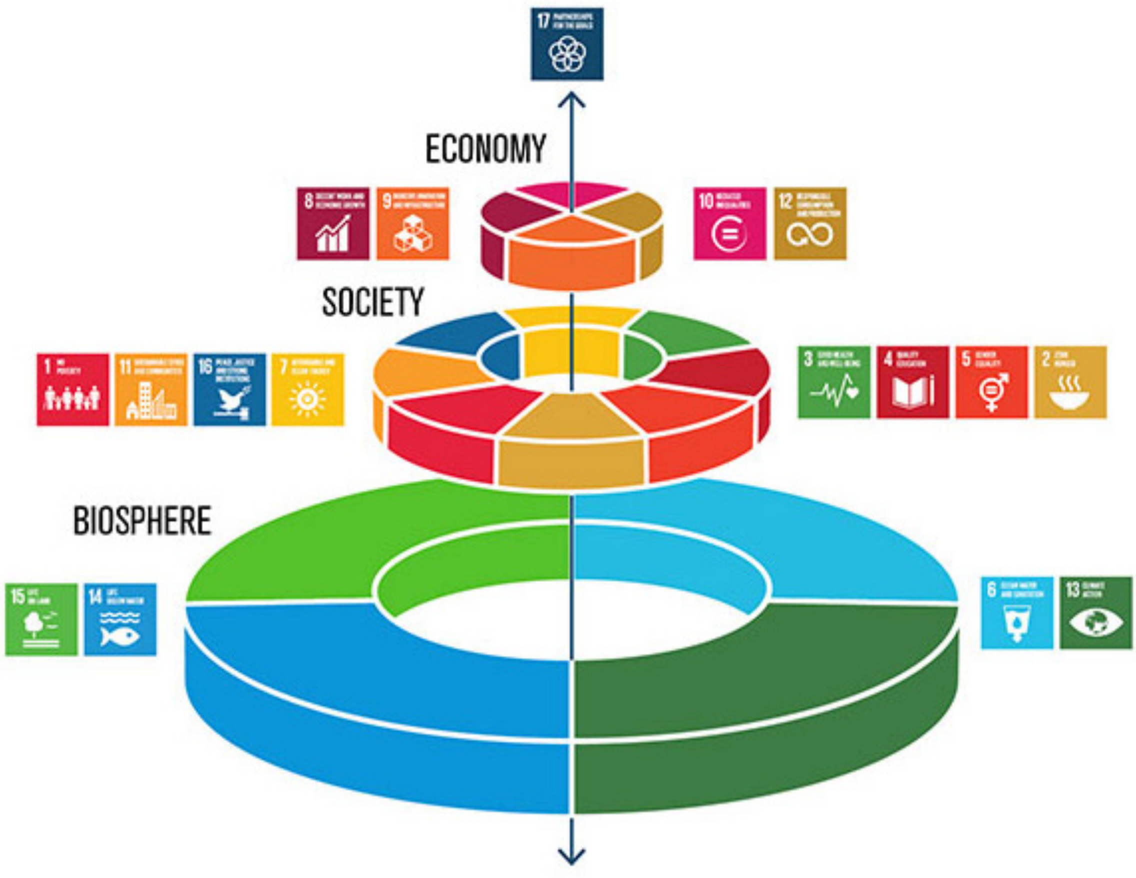

Figure 1: The SDG wedding cake (**Source:** Stockholm Resilience Centre)

1 A number of the SDGs are linked when it comes to their implications for natural capital. For examples SDGs 3, 6, 9 and 11 are linked through air quality and SDGs 8 and 12 through reductions in material inputs. Section 3 brings the SDGs together where necessary.

SDG 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

SDG 3: Ensure healthy lives and promote well-being for all at all ages

SDG 6: Ensure availability and sustainable management of water and sanitation for all

SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable

SDG 12: Ensure sustainable consumption and production patterns

SDG 13: Take urgent action to combat climate change and its impacts

SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development

SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

For each of these goals, there are targets and for many of the indicators have been agreed (for 2020 in some cases and 2030 in most others). Annex I lays out the full set of targets and corresponding indicators. These indicators require an increase in a component of natural capital, relative to the present situation and/or relative to the situation that would exist at the target date if they are to be attained. The aim of the proposed exercise is to estimate this required increase in stock of natural capital, in physical terms and monetary terms where possible, recognizing that the exercise has many uncertainties that need to be recorded and taken into account. Thus, the increase in natural capital is expressed as a range and given that this is a target it makes sense to refer to it **as a natural capital gap consistent with the SDGs**.

The first question is what purpose would such estimates of the natural capital gap serve? We would argue that they would establish a link between key SDG goals and the natural capital needs they embody, focusing attention on measures to increase that component of the stock of capital in such a way that the specific goals are met. To be sure, the measures will involve various other forms of capital as well and the amounts of these needed can also be estimated. Under a weak sustainability view, one would argue that the indicators representing the goals should only be targeted if the increase in natural capital they embody can be achieved with less of other forms of capital, so that the actions represent an increase in total capital. In the context of the SDGs, however, it does not make sense to take such a position, as the goals are seen as something worth pursuing in their own right. Hence, we would go for a strong sustainability view, where the increase in natural capital is desirable to meet the stated SDG objective and cannot be traded off against other forms of capital.[2] In this case, measures that increase the stock of natural capital can still be evaluated, but now the aim is to select those that attain the SDGs in the most efficient way, i.e. involving the least amount of sacrifice of other forms of capital.

2 See Pearce *et al.* (1989) for a discussion of weak and strong sustainability. The degree to which other forms of capital can replace natural capital is debateable. Recent work by the Institute for New Economic Thinking indicates the substitutability of natural capital is quite low, which supports the case for a strong sustainability view. See https://www.inet.ox.ac.uk/files/Substitution_paper_Final.pdf.

The second question is at what levels of aggregation should the exercise be conducted? The table in Annex I indicates what levels of estimation are possible for the different components. All of them need some data from the bottom up if estimates are to be derived in a meaningful way and the usefulness of the exercise is really at the national, sub-national or biome level. In any event, the proposal is to conduct the estimation at a national level where possible and at the level of a biome such as a marine water body where that is more appropriate. Aggregation to a global estimate has been done drawing on the national or global data.

The third question is what baseline should the gap in natural capital be measured against? One is the difference between the level needed to meet the SDGs and the current level and a second is the difference between the level needed for the SDGs and the level that would exist at the future date in the absence of the goal. The second is more useful when comparing gap against measures needed to fill it at the future date, but it requires further assumptions about how the amount would evolve under a "business and usual" (BAU) scenario. In the estimates presented in Section 5 the present level has been taken but this is something that merits further discussion.

The approach taken here is to find a link between the SDG targets and the changes in natural capital required to meet them. A complementary approach taken in another GGKP Natural Capital working paper (GGKP, 2020a) is to take each type of natural capital and identify, if possible, an indicator that links the condition of that asset to the SDGs. Links are not made for all types of natural capital: the ones where an indicator is established are: water resources (proportion of bodies with good ambient water quality); trends in forest extent; and change in the extent of water-related ecosystems. The indicators proposed in the working paper (GGKP, 2020a) do not give measure the change in natural capital either in physical or monetary terms; rather they draw attention to areas where such capital has a link (qualitative or quantitative) to a given SDG. In this sense, they complement the approach taken here, which seeks to make a quantitative link (ideally in monetary terms) between the amount of natural capital and the SDGs.

The next section looks at the selected SDGs and indicators in some detail and proposes a methodology for estimating the natural capital gap related to that SDG where this is feasible.

3. SDG TARGETS AND METHODS TO ESTIMATE THE IMPLIED NATURAL CAPITAL GAP

For the nine SDGs, there are 14 targets with indicators that imply an increase in the stock of some form of natural capital. Each target is reviewed and the approach to be taken to estimate the implied natural capital gap is presented. In some cases, targets can be combined and represented by a single measure of natural capital change. Where this is the case such an aggregation has been carried out.

Before going into the details of the estimates made, it is worth drawing attention to a platform of tools that assess natural capital movements at different levels of granularity. Another GGKP Natural Capital working paper on tools and platforms has put together a detailed description of the tools and their possible applications (GGKP, 2020b). As research proceeds, it will be possible to use some of these tools to measure the changes in natural capital associated with meeting different SDGs.

Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

The proposed indicator of **"per cent land under productive and sustainable agriculture"** does not capture all the targets of sustainable food production, but it has a clear link to the item "implement agricultural practices that help maintain ecosystems…and that progressively improve land and soil quality".[3]

Current monetary estimates of natural capital include the value of agricultural land. For cropland and pasture land, the main service is the market food products derived valued at the market prices net of costs of production and taxes. The discounted value of the stream of these net incomes is the value of the land from which the services are obtained. This raises the question of how to obtain data on net incomes now and in the future? The World Bank (2006) valuation study used external estimates of the "rental rate", i.e. percentage of the price that is net income and combined it with data on prices from the UN Food and Agriculture Organization (FAO). For future years, prices were assumed constant and a horizon of 25 years was imposed. The discount rate used was 4 per cent. As in the case of forests, these simplifications may be justified on practical grounds but they mask the problems of changing future prices, and the possibility of declining yields due to degradation in some locations or of increasing yields due to technological improvements in others. In addition to the provision of food, agricultural land also provides other ecosystem services, the scale of which depend on how it is managed. Estimates of such services have been made in the literature for different kinds of land cover at the disaggregated spatial scale across the globe (Costanza *et al.,* 2014; Sutton *et al.,* 2016).

3 The target is also linked to target 15.3, which states: "By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world". The indicator there is proportion of land that is degraded over total land area.

The role of natural capital in relation to the SDG can be defined by the difference between the per cent of land that is not under productive agriculture now and what that would be in 2030 if no action is taken, i.e. business as usual (BAU). From that one can calculate the loss of natural capital under BAU. A target value for the SDG for 2030 can be set and a natural capital "gap" can be defined in physical terms as:

$$A_{2030,SGD} - A_{2030,BAU}$$

Where $A_{2030,BAU}$ is the area of non-productive land under BAU in 2030 and $A_{2030,SGD}$ is the area of non-productive land that meets the SDG target. The gap can also be expressed in value terms as:

$$V_{2030,SGD} - V_{2030,BAU}$$

Where $V_{2030,BAU}$ is the loss in value of the non-productive land due to it being degraded under BAU in 2030 and $V_{2030,SGD}$ is the loss in value if the area that is degraded meets the SDG target.

Issues: Definitions of non-productive land are difficult to agree upon and estimates vary widely (Gibbs and Salmon, 2015). There is no clear consensus as to the area of degraded land, even at the national level. The FAO states that an estimated 52 per cent of the land used for agriculture worldwide is moderately or severely degraded, and nearly 2 billion hectares—an area twice the size of China—is seriously degraded, sometimes irreversibly.[4] This makes an exercise that is comparable globally across countries difficult, but it should be possible to agree on different land categories at the national level. The World Resources Institute (WRI) and other researchers have collected a lot data on degraded lands and we have been in discussion with them about possible use of it.

Proposal: In the next section, an estimate the natural capital gap is made with respect to agricultural land based on a common definition of degradation and agreed targets for the SDG for 2030. This can later be compared to the costs of different measures for the remediation of these lands, which would give an estimate of the amount of other forms of capital needed to close the natural capital gap.

Target 2.5: By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.

The proposed indicator is the per cent of local breeds that risk extinction. A physical measure of the associated natural capital would be the stock of genetic local breeds and the value measures would be the flow of services provided by the stock. While prevention of extinction has been valued for selected species the data do not cover all such species. There is, moreover, no value for the reduced risk of extinction and no estimates of the amount by which risk is reduced. Existing measures of natural capital do not include a value for species as such. It is assumed that the flow of services from them are captured in the biomes that are valued (forests, woodlands, grasslands and freshwater bodies in the case of terrestrial biomes and open oceans, coastal systems, wetlands and coral reefs in the case of marine biomes).

Proposal: For the present not to include possible loss of genetic diversity as a separate category for which a natural capital gap is estimated. There is, however, one platform that tracks the effects of changes in genetic diversity. It is called "ENCORE" and is described in detail in GGKP (2020b). It may be possible to use this to make an estimate of the gain in natural capital from meeting target 2.5.

Target 3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.

Target 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management. (Link to 3.9)

4 http://www.fao.org/land-water/land/land-assessment/en

The proposed indicators are the rates of mortality attributable to air and water pollution. The link to natural capital is through seeing clean air and water as part of the stock of natural capital and setting the losses due to pollution as the cost arising from the loss of natural capital. The natural capital gap would be the difference in deaths in 2030 with no change in air and water quality and the deaths if air and water quality meet their target values. For air quality, the proposed target value is mortality associated with a given concentration of $PM_{2.5}$ above 10µg/M^3 (proposed by the World Health Organization and possibly reflecting natural concentrations in the atmosphere). For water, the target would be a reduction of water pollution required to bring mortality to zero under the assumption that all households have access to safe water and sanitation.

The physical natural capital gap would be the deaths due to air and water pollution under BAU in 2030 and those under the SDG targets. The value equivalent would be the losses associated with the excess deaths, valued using methods such as Disability Adjusted Life Years (DALYs) (see Cropper and Khanna, 2014).

Proposal: Valuations of the natural capital gap in physical and monetary terms in relation to air and water pollution can be made for almost all countries and Section 5 reports some figures. Measures to reduce such emissions and their demands in terms of other forms of capital have been studied in some depth and can be compared against the values of the natural capital gap.

These measures also cover the health component of the natural capital benefits of the SDGs in relation to SDG 6.3 and the benefits of air quality in SDG 11.6. In the case of the latter, no further estimate of the natural capital gap is required.

Target 6.4.: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

The proposed indicators are change in water-use efficiency over time and a measure of water scarcity: freshwater withdrawal as a proportion of available freshwater resources.

Water is a part of the stock of natural capital, but is rarely valued as such in money terms. The exception is depletion of "fossil water", i.e. water that is not replenished. The value of water is normally captured in the value of the services from the ecosystems within which it is located. The current estimates of the wealth stock of nations (UNEP or World Bank) do not include a value for water.

In terms of the natural capital gap for this target, therefore, a physical measure can be constructed but not a monetary one. Hejazi *et al.* (2013) have estimated water scarcity using Raskin's definition of scarcity as the ratio of total water withdrawal (TWW) to total water availability (TWA). The index indicates no scarcity when it is below 0.1, low scarcity for values of between 0.1 and 0.2, moderate scarcity for values between 0.2 and 0.4, and severe scarcity for values greater than 0.4. Estimates of scarcity under a range of BAU scenarios have been made. The natural capital gap can be interpreted as the difference between the actual and target values for scarcity, based on this measure, in 2030.

Proposal: For the selected countries estimates of water scarcity under agreed scenarios and target values in 2030 can be made. Measures to reduce the gap can be identified and costed. No monetary gap estimate is proposed.

Target 8.4: Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries.

Target 12.2: By 2030, achieve the sustainable management and efficient use of natural resources.

The proposed indicators are: 8.4.1 – material footprint, material footprint per capita and material footprint per GDP; and 8.4.2 – domestic material consumption, domestic material consumption per capita and domestic material consumption per GDP.

Material use is expected to increase as countries grow and as the gap between the developed countries and developing countries (the emerging economies in particular) narrows. At the same time, increases in resource efficiency and recycling and reuse are expected from a relatively low base.[5] The Organisation for Economic Co-operation and Development (OECD) has recently completed a report on Global Material Resources Outlook (OECD, 2019) and the United Nations Environment Programme (UNEP) has worked on the same topic (UNEP, 2019). The data in these reports provide estimates of resource use now and in 2060 for different regions and countries, and provide an estimate of the materials savings from an increase in resource efficiency.

The relationship between reduced use of materials and the natural capital gap, however, is not straightforward. The gap is interpreted as the present value of the increased services provided by enhancing the stock of natural capital. With less material use the benefits are not simply the reduction in materials use. Instead they are made up of: a reduction in the loss of ecosystem services by having less impact on the environment; more materials being available for future generations to use, the value of which is based on the scarcity rent of the current extraction; and an increase in GDP brought about by creating innovation and developing new areas of economic activity related to materials recovery. Possible estimates from these three sources are discussed in Section 5.

Proposal: Data from the OECD and UNEP studies have been used to estimate savings values for 2030 and, based on that, estimate the natural capital gap in physical and monetary terms in Section 5. This may be compared against costs of measures to increase resource efficiency.

Target 9.4: By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.

The specific indicator for this target is emissions of CO_2 per unit of GDP. Emissions targets for this gas exist at the global level and for most countries. The same applies for emissions under BAU. The difference between the two, converted into emissions of CO_2, would then constitute the natural capital gap for 2030 in physical terms. In monetary terms, the gap would be valued at the global social cost of carbon, for which a range of values for 2030 are available (US Government, 2013).

Proposal: Estimates of the natural capital gap with respect to CO_2 emissions have been made for selected countries for 2030 in physical and monetary terms in Section 5.

Target 13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

The specific quantitative indicator for this target is number of deaths, missing persons and persons affected by disaster per 100,000 people. There is no global target reduction, but individual countries will probably have some such target. The natural capital here is both the climate-related atmosphere and the resilience of the natural environment to climate related hazards. The former depends both on limiting emissions of GHGs and the latter on investing in protection against disasters through increases in physical and natural capital. A loss of life and injury caused by disasters can be debited partially to a decline in natural capital and one component of that decline is the value attached to these losses. Methods for valuing them are well developed and can be used the value the gap associated with the target. Estimates based on this and issues arising in making them are discussed in Section 5.

Target 14.1: By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information.

There are several indicators for this target:

14.1.1 Index of coastal eutrophication and floating plastic debris density

14.2.1 Proportion of national exclusive economic zones managed using ecosystem-based approaches

14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations

14.4.1 Proportion of fish stocks within biologically sustainable levels

14.5.1 Coverage of protected areas in relation to marine areas

14.6.1 Progress by countries in the degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing

It is clear that the indicators are interrelated – 14.1, 14.2, 14.3, 14.5 and 14.6 all have an impact on 14.4, which is one of the marine ecosystem service flows. Others, such as the level of eutrophication, are also related to ecosystem service flows and thereby on the value of the biome in terms of natural capital.

5 A recent assessment puts the degree to which the world is following the circular economy approach as only at about nine per cent. See: https://www.circularity-gap.world.

The analysis of the links is complex. It would have to be carried out for a selected marine water body and would require biophysical modelling. The status of work in this area is also limited. In a comprehensive review of the marine fishery sector in the context of greening the economy, UNEP (2011) does not attempt to provide an estimate of the capital value of different marine waters. Likewise, earlier efforts at measuring the natural capital stock such as World Bank (2006) and the Inclusive Wealth study by the UN do not deal with this sector. There are, however, a few separate estimates of the value of marine systems. One (Hoegh-Guldberg *et al.*, 2015) puts the bounty of the ocean produces $2.5 trillion in gross marine product per year, a roughly 10 per cent return on its asset value of $23 trillion. Much higher estimates are made by Costanza *et al.,* 2014 (the flow of services is estimated at $49.7 trillion, of which $21.9 trillion was for ecosystem services (ESS) from the open oceans and $27.7 trillion from the coastal areas).

A large chunk of these values are not accounted and captured in the conventional decision-making framework of the countries.[6] The rate of loss of natural capital in these biomes is significant: Today, 60 per cent of the world's major marine ecosystems that underpin livelihoods have been degraded or are being used unsustainably. By the year 2100, without significant changes, more than half of the world's marine species may stand on the brink of extinction.[7] Looking at specific pollutants, the environmental damage to global marine ecosystems caused by plastics has been estimated at $13 billion per year, including financial losses to fisheries and tourism and time spent on clean-up activities (UNEP, 2014).

Proposal: Linking natural capital losses to the SDG indicators requires some specific modelling of a given marine biome. Discussions with marine experts indicate that considerable data are available for EU member states on the indicators 14.1 and 14.2, but their impact on natural capital stocks needs further research. This is not possible, however, within the framework of the present study.

Target 15.1: By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements.

The indicators for 15.1 are forest area as per cent of all land area and per cent of sites for biodiversity that are protected. Note that the target is 2020, which is unrealistic given the short time period. It may be better therefore to consider a target date of 2030.

For forest area, considerable data exist on the different types of forest and the value of services provided. Estimates have also been made in the extensive work of Aklemade *et al.,* 2006, of forest area losses if no further actions were taken for the period 2000–2050. These are of course the mirror image of the benefits to be gained by preventing that loss and are estimated at 9 per cent of 2000 boreal forest stocks, 19 per cent of temperate forest stocks and 12 per cent of tropical forest stocks. Estimates of the value of these losses were made in Markandya and Chiabai (2013). Given a target reduction in these losses by 2030, an estimate of the natural capital gap can be derived for different regions and forest biomes. With some further disaggregation, the figures can be downscaled for selected countries.

For the natural capital gains from increasing sites of biodiversity that are protected, the point of departure is the TEEB-related study of Hussain *et al.* (2011). They analyse a slightly different expansion: of 20 per cent by 2030, but from their annual benefits and costs of the programme one can make an estimate of the benefits for a target programme. One can assume, as they do, that currently 10 per cent of all eco-regions of the world are protected, giving a total protected area of 13.2 million km^2 in 2000 (i.e. the same as the CBD estimate).

6 For further discussion of these figures and some criticisms of them, see Pendleton *et al.* (2016) and Markandya (2016).

7 http://www.unesco.org/new/en/natural-sciences/ioc-oceans/focus-areas/rio-20-ocean/blueprint-for-the-future-we-want/marine-biodiversity/facts-and-figures-on-marine-biodiversity . http://www.unesco.org/new/en/natural-sciences/ioc-oceans/priority-areas/rio-20-ocean/blueprint-for-the- future-we-want/marine-biodiversity/facts-and-figures-on-marine-biodiversity/.

In terms of benefits, Hussain *et al.* estimate the biophysical changes resulting from the protection and value the ecosystem services that such a change provides. The areas that increase in most parts of world include grassland and forest, but in some cases protected areas are created by reducing land from these biomes as well. They provide estimates of the services gained into two groups: those related to the capture of carbon and the rest. The reason for separating the two is that the former has, in their view, much greater uncertainties and constitutes global benefits, while the rest are, in large part, local benefits. The benefits are then reported as a lower bound (without carbon storage benefits) and an upper bound (with carbon storage benefits).[8]

Proposal: Estimates of the natural capital gap relative to current stocks and stocks in 2030 in the absence of the SDG have been made for selected regions with respect to arresting forest loss and protecting biodiversity through increased areas being brought under protection. Results are reported in Section 5.

Target 15.2: By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.

For 15.2, the indicator is "progress toward sustainable forest management", but the target has a statement of halting deforestation as well. As with 15.1, the target date is not realistic and 2030 is considered as a better target. The interpretation to be given to this target is difficult as target 15.1 requires an increase in forest area, which would imply a halt to deforestation. The statement of increasing afforestation and reforestation substantially are not quantified in the SDG, but they were given a quantitative value in the Aichi Targets adopted as part of the Convention of Biological Diversity's Strategic Plan for Biodiversity 2011–2020, in Nagoya, Japan, in 2010. These targets significantly influenced SDGs 14 and 12. For afforestation and reforestation, the Aichi target required that 150 million hectares will be planted over the period 2013 to 2020. Further details are in Markandya (2018).

Proposal: The natural capital increase associated with such a programme has been estimated based on existing data of the values of afforestation and reforestation, but tying them to the SDG target is problematic. The proposal, therefore, is that no additional estimate be made of the natural capital gap in relation to this target.

Target 15.5: Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.

As with the other targets of SDG 15, the target of 2020 is not realistic and needs reappraisal. The indicator is the rate of loss of biodiversity.

As was noted for target 2.5, valuation of biodiversity as such is not undertaken in estimates of the stock of natural capital. Goals that target different ecosystems, if realized, would reduce losses of biodiversity, particularly in the case of target 14.1, 15.1 and 15.2. A separate estimate of the natural capital gap for this indicator, therefore, would imply double counting and not be appropriate.

Proposal: No valuation is undertaken of this target.

8 The carbon benefits are estimated on two bases: first from models in which a carbon target has been set and in which one can calculate the cost per ton reduced; and second from models that estimate the damages done per ton emitted via climate change. See Hussain *et al.*, 2011 for details.

4. SUMMARY OF PROPOSED MEASUREMENT OF NATURAL CAPITAL GAPS LINKED TO THE SDGS

Table 1 summarizes the links to natural capital for the selected SDGs and possible sources of data for estimating them. Particular issues where clarity is needed are:

1. Are the methods for valuing natural capital appropriate?
2. Which baseline should be used for estimating the gap?
3. Is the proposed combining of some targets acceptable?
4. Are the proposed indicator targets (and some modifications relative to the UN values) acceptable?
5. How do you handle the issues relating to SDG 14?

Table 1: Summary of Proposed Actions

SDG Goal	Natural Capital Form	Natural Capital Deficiency	Estimation	Data Sources
Goal 2: End Hunger	Land biomass	Restoration of degraded land	Value of land services when restored	Various. WRI. National.
Goal 3: Healthy Lives; Goal 11: Safe Cities	Quality of air Quality of water	Reduction of pollutants in air and water	Reduced DALYs from lower levels of air and water pollution	Various. WHO, World Bank, National
Goal 6: Water and Sanitation	Quality and quantity of water	Reductions in water scarcity	No monetary valuation; physical indicator quantified	National.
Goal 9: Resilient Infrastructure	Atmosphere to sustain a stable climate	Reductions in emissions of GHGs	Valued using the social cost of carbon	Various. National
Goal 12: Sustainable consumption and production	Terrestrial biomes that deliver ecosystem services	Less use of natural materials in consumption and production	Value of reduced environmental impacts from saved resources	OECD. UNEP. National.
Goal 13: Combat climate change and its impacts	Atmosphere to sustain a stable climate	Loss of life and injury resulting from disasters	Value of lives saved and of reduced injuries	EM-Dat. DesInventar database
Goal 14: Sustainable use of oceans, seas and marine resources	Marine biomes that deliver ecosystem services	Reduced loss of marine services and marine capital stock	Modelling of links of services to the Indicators; use of existing estimations of marine ESS	Costanza *et al.* Hoegh-Guldberg, O. *et al.* EU databases.
Goal 15: Terrestrial Ecosystems	Terrestrial biomes that deliver ecosystem services	Reduced flow of ESS from these systems	Physical data and valuation studies for forests and protected areas	Alkemade *et al.*, and Globio team National

5. PRELIMINARY ESTIMATES OF THE NATURAL CAPITAL GAP

This section provides some preliminary estimates of the natural capital gap for a number of the SDGs discussed in the previous section.

RESTORATION OF DEGRADED LAND

In this exercise, estimates of ESS loss due to land degradation are taken from Sutton *et al.,* (2016). They use data on the Human Appropriation of Net Primary Productivity (HANPP) as a supply side measure of land degradation. This provides an estimate of the actual net primary productivity of land, which is compared against its potential productivity. The percentage loss is then multiplied by the area to which it applies, times the ecosystem service values per year per hectare for such a type of land cover when it has no degradation. The analysis is done at a highly disaggregated level. Based on this they derive a comprehensive set of estimates of losses by country of ESS due to land degradation.

To link these estimates to overall land areas to be remediated, and to apply target values for remediation, estimates are needed of land that could be classified as degraded. Unfortunately, such estimates vary and are not well determined (Gibbs and Salmon, 2015). The global range is from less than 1 billion ha, to over 6 billion ha, with equally wide disagreement on its spatial distribution. An estimate in the middle of the range is Bai *et al.,* (2008) based on the GLADA dataset, with national level estimates for all countries. It has been criticized, especially for its estimates in the humid tropics, but it is comprehensive and other datasets such as GLASOD and FAO TERRAsat were not accessible. Hence, for this exercise the figures from Bai *et al.,* have been used, recognizing that the results could be different if another dataset were applied. Some discussion of possible bias in the estimates of natural capital due to the data used for degraded land follows.

Bai *et al.,* estimate that overall around 27.4 million km^2 have been degraded globally over the period 1981–2003. This amounts to about 21 per cent of the world´s land area. The corresponding loss of ESS, according to Sutton *et al.,* however, is only about 9 per cent, indicating that the degraded areas do not on average contribute as much as non-degraded ones. To calculate the natural capital gap, an estimate of the amount of degraded land that is to be restored is required. The SDGs do not give a figure for what per cent of degraded land should be restored by 2030. One target linked to the SDGs is the Bonn Challenge, which demands restoring 350 million hectares by 2030. As of November 2017, 39 countries and a number of NGOs had made commitments to making a contribution to this restoration. If this were to be met, it would amount to remediating about 13 per cent of all degraded land by 2030.

The value of the natural capital can be estimated from the data in Sutton *et al.* The calculations depend on where the remediation is undertaken as the value per hectare remediated varies across countries. Table 2 gives the values in decreasing order for a sub-group of 40 countries (out of a total of 206 in the database), selected to give reasonable regional and development level coverage. The highest value of lost services per hectare is in Denmark, followed by Burkina Faso and Turkey. The values per hectare do not follow any clear regional or development pattern but seem to reflect where the most valuable land is degraded.

One way to allocate the 350 million hectares is proportional to national shares in total degraded land. Another is to undertake the restoration where the values of the land were highest, going down the list until the target reduction was met. A third way would be to base it on national commitments to the Bonn Challenge. The calculations assume that the value of capital is the present value of the stream of net benefits in perpetuity, discounted at 4 per cent. To get net benefits it is assumed that the figures given by Sutton *et al.,* for the ESS flows are net of costs. Finally, the present value of the natural capital missing due to the degradation needs to take account of the time it would take to get the ESS going again. It is assumed that the programme of remediation would be spread out equally over the decade 2020–2030 (11 years) and it would take five years for each "slice" to become effective.

Table 2 gives the values for the natural capital gap for the first two methods of allocating the reduction. Based on method 1, the global gap is $13.7 trillion, and based on method 2 it is about $29.6 trillion. These numbers are of course subject to error. If the area of land that is remediated is set at 350 million hectares, the amount of ESS lost is estimated here as about 13 per cent of the total from all degraded land. But the 13 per cent figure is based on the estimated degraded land in Bai *et al.,* 2008. If the total amount of degraded land were taken as half that (which may well be the case), then the 350 million hectares would amount to 26 per cent of the total ESS lost due to degradation and the global natural capital gap would be $27.4 trillion by method 1 and $59.2 trillion by method 2. Equally, if the true figure were double that of Bai *et al.,* then the natural capital gap would be half that given in Table 2.

Table 2: Land Degradation and the Natural Capital Gap

Nº	Country	Degraded Area[1]	Total Area[2]	As % of Total	ESV % of Total[3]	ESV Loss[3]	ESV Loss Per Ha.	ESV Per Ha.	Present Loss of NC	Gap to 2030 Bonn Challenge			Costs of Filling Gap			
										Method 1	Method 2		Method 1		Method 2	
		Km[2]		%		Mn. $/Yr.	$/Yr.		$Bn.	$Bn.	$Bn.	Ha.000	$Bn. LB	$Bn. UB	$Bn. LB	$Bn. UB
1	Denmark	91	42,400	0.2%	2.1%	576	63,297	6,506	10	1	10	9	0.0	0.0	0.0	0.1
2	Burkina Faso	9,255	274,000	3.4%	22.6%	29,748	32,143	4,806	506	65	506	935	0.3	1.9	2.1	14.8
3	Turkey	30,851	769,600	4.0%	21.6%	76,298	24,731	4,580	1,299	166	1,299	4,020	0.9	6.3	7.1	49.3
4	Afghanistan	7,658	652,000	1.2%	14.5%	18,167	23,723	1,926	309	39	309	4,786	0.2	1.6	1.8	12.2
5	Albania	2,334	27,000	8.6%	30.2%	4,041	17,314	4,941	69	9	69	5,019	0.1	0.5	0.5	3.7
6	Nigeria	91,443	910,800	10.0%	23.2%	112,025	12,251	5,311	1,907	244	1,907	14,163	2.7	18.7	21.0	146.1
7	Senegal	34,655	192,500	18.0%	18.2%	30,171	8,706	8,589	513	66	513	17,629	1.0	7.1	8.0	55.4
8	Uganda	41,506	197,100	21.1%	22.0%	30,730	7,404	7,089	523	67	523	21,779	1.2	8.5	9.5	66.3
9	India	592,498	2,973,200	19.9%	20.3%	360,725	6,088	5,977	6,139	784	6,139	81,029	17.4	120.9	136.1	946.7
10	Morocco	67,399	446,300	15.1%	30.9%	31,885	4,731	2,309	543	69	543	87,769	2.0	13.8	15.5	107.7
11	Russia	2,802,060	16,381,400	17.1%	7.4%	1,047,474	3,738	8,637	17,827	2,277	17,827	350,602	82.2	571.9	643.8	4,477.0
12	South Africa	351,555	1,214,500	28.9%	24.0%	110,377	3,140	3,788	1,879	240			10.3	71.7		
13	Pakistan	20,644	770,900	2.7%	2.9%	6,214	3,010	2,797	106	14			0.6	4.2		
14	Ethiopia	296,812	1,000,000	29.7%	17.7%	85,419	2,878	4,834	1,454	186			8.7	60.6		
15	France	46,691	550,100	8.5%	5.2%	13,201	2,827	4,651	225	29			1.4	9.5		
16	Cambodia	77,958	177,000	44.0%	19.3%	20,000	2,565	5,858	340	43			2.3	15.9		
17	Bangladesh	68,422	130,000	52.6%	11.7%	16,971	2,480	11,193	289	37			2.0	14.0		
18	Brazil	1,881,702	8,358,000	22.5%	6.7%	453,894	2,412	8,143	7,725	987			55.2	384.0		
19	Kazakhstan	487,083	2,699,700	18.0%	11.1%	111,518	2,290	3,733	1,898	242			14.3	99.4		
20	Indonesia	1,028,942	1,811,600	56.8%	13.8%	227,740	2,213	9,134	3,876	495			30.2	210.0		
21	USA	1,983,886	9,161,900	21.7%	8.0%	418,236	2,108	5,689	7,118	909			58.2	404.9		
22	Argentina	902,438	2,737,000	33.0%	8.9%	189,110	2,096	7,800	3,219	411			26.5	184.2		
23	UK	23,506	241,900	9.7%	4.3%	4,549	1,935	4,405	77	10			0.7	4.8		
24	Chile	77,230	744,000	10.4%	5.4%	13,853	1,794	3,443	236	30			2.3	15.8		
25	Mexico	487,804	1,908,700	25.6%	10.4%	86,663	1,777	4,358	1,475	188			14.3	99.6		

Nº	Country	Degraded Area[1]	Total Area[2]	As % of Total	ESV % of Total[3]	ESV Loss[3]	ESV Loss Per Ha.	ESV Per Ha.	Present Loss of NC	Gap to 2030 Bonn Challenge			Costs of Filling Gap			
										Method 1	Method 2		Method 1		Method 2	
		Km²		%		Mn. $/Yr.	$/Yr.		$Bn.	$Bn.	$Bn.	Ha.000	$Bn. LB	$Bn. UB	$Bn. LB	$Bn. UB
26	Malawi	30,869	94,100	32.8%	7.4%	5,055	1,638	7,220	86	11			0.9	6.3		
27	Myanmar	358,887	657,600	54.6%	15.1%	55,757	1,554	5,624	949	121			10.5	73.2		
28	Germany	32,479	348,800	9.3%	2.7%	4,861	1,497	5,133	83	11			1.0	6.6		
29	Botswana	97,831	567,000	17.3%	3.5%	13,094	1,338	6,620	223	28			2.9	20.0		
30	Australia	1,994,268	7,682,000	26.0%	6.8%	223,570	1,121	4,283	3,805	486			58.5	407.0		
31	China	2,193,697	9,388,000	23.4%	6.6%	208,381	950	3,355	3,546	453			64.4	447.7		
32	Tanzania	386,256	883,600	43.7%	7.4%	34,885	903	5,322	594	76			11.3	78.8		
33	Nepal	54,704	143,000	38.3%	7.0%	4,271	781	4,296	73	9			1.6	11.2		
34	Canada	1,985,085	9,094,000	21.8%	4.4%	146,583	738	3,641	2,495	319			58.3	405.1		
35	Belgium	5,404	30,200	17.9%	2.7%	395	731	4,903	7	1			0.2	1.1		
36	Zambia	454,630	743,400	61.2%	6.1%	29,994	660	6,567	510	65			13.3	92.8		
37	CAR	126,927	623,000	20.4%	2.9%	6,922	545	3,836	118	15			3.7	25.9		
38	Congo Rep.	201,614	342,000	59.0%	3.3%	9,467	470	8,420	161	21			5.9	41.1		
39	Egypt	36,514	995,000	3.7%	2.8%	1,065	292	381	18	2			1.1	7.5		
40	Korea	54,091	98,700	54.8%	1.1%	365	67	3,474	6	1			1.6	11.0		
	World	27,400,000	129,606,000	21.1%	9.2%	6,320,426	2,307	5,307	107,569	13,741	29,645		570	3,965	846	5,879

LB: Lower Bound. *UB*: Upper Bound
1. Bai *et al.* (2008).
2. World Development Indicators.
3. Sutton *et al*. (2016).

Table 3: Air and Water Pollution and the Natural Capital Gap

	Air Pollution $PM_{2.5}$		Water Pollution	
	Deaths	Welfare Loss	DALYS	Welfare Loss
	Number	USD$Mn. PPP	´000	USD$Mn. PPP
Algeria	7,845	8,855	306.4	15,718
Armenia	2,401	1,357	7.0	180
Australia	777	3,361	3.2	636
Austria	3,573	15,797	1.5	294
Azerbaijan	5,994	8,823	71.8	4,804
Bahrain	188	798	0.3	53
Bangladesh	154,898	27,452	3,384.8	27,267
Belarus	9,816	14,963	3.2	222
Belgium	5,858	24,190	2.0	368
Benin	6,350	679	433.7	2,108
Bolivia	2,667	1,179	159.1	3,198
Bosnia & Herz.	1,882	1,401	1.7	58
Brazil	62,246	82,612	1,181.2	71,261
Brunei	42	274	0.4	107
Bulgaria	7,297	10,299	2.3	150
Burkina Faso	10,410	877	1,195.1	4,577
Burundi	7,317	252	695.7	1,089
Cambodia	19,595	3,637	573.5	4,838
Cameroon	16,392	2,785	762.0	5,885
Canada	9,466	40,460	5.9	1,153
Central African Republic	5,161	134	221.0	261
Chad	11,067	1,290	748.4	3,965
Chile	4,309	10,855	19.4	2,217
China	1,625,164	1,589,767	4,534.1	201,607
Colombia	14,636	15,046	130.8	6,114
Congo, Dem. Rep.	62,412	1,964	5,022.6	7,184
Congo, Rep.	3,393	1,400	78.6	1,475
Costa Rica	629	748	7.3	394
Côte d'Ivoire	16,264	2,994	979.3	8,194
Croatia	2,716	6,392	0.8	85
Cuba	3,052	5,603	13.4	1,120
Cyprus	303	988	0.5	77
Czech Republic	6,640	20,521	2.0	283
Denmark	1,632	7,011	1.0	198
Dominican Republic	3,828	3,792	58.7	2,641
Ecuador	3,156	2,721	71.4	2,797
Egypt, Arab Rep.	39,118	31,545	443.2	16,245
El Salvador	2,182	1,306	38.4	1,045
Estonia	504	1,451	0.3	38
Ethiopia	71,018	5,059	5,928.5	19,196
Finland	653	2,612	0.8	141
France	21,138	81,840	2.1	368

	Air Pollution $PM_{2.5}$		Water Pollution	
	Deaths	Welfare Loss	DALYS	Welfare Loss
	Number	USD$Mn. PPP	´000	USD$Mn. PPP
Georgia	7,995	4,127	15.9	374
Germany	41,485	180,099	15.4	3,040
Ghana	17,524	4,446	672.0	7,750
Greece	8,320	22,681	0.0	2
Guatemala	5,546	2,879	212.1	5,005
Guinea	10,147	634	463.9	1,318
Haiti	7,878	716	244.4	1,010
Honduras	4,013	1,269	67.8	975
Hong Kong SAR, China	9,235	46,387		0
Hungary	7,435	19,428	2.9	347
Iceland	21	89	0.0	9
India	1,403,136	505,103	24,996.9	409,020
Indonesia	162,410	125,119	1,866.0	65,342
Iran, Islamic Rep.	21,680	30,599	116.1	7,450
Iraq	10,372	13,658	836.5	50,067
Ireland	558	2,562	0.0	0
Israel	2,201	7,405	0.0	0
Italy	29,482	105,464	3.3	539
Japan	64,428	240,353	29.8	5,056
Jordan	1,055	990	21.4	914
Kazakhstan	12,317	26,084	131.9	12,693
Kenya	18,237	3,102	1,176.2	9,094
Korea, Rep.	20,370	70,948	18.9	2,993
Kuwait	547	3,671	0.5	158
Kyrgyz Republic	4,952	981	60.1	542
Lao PDR	7,251	2,409	134.5	2,032
Latvia	1,407	3,482	0.5	56
Lebanon	1,816	2,660	10.2	681
Liberia	2,985	118	317.0	570
Libya	1,956	3,506	7.0	569
Lithuania	2,270	6,343	0.0	1
Luxembourg	188	1,468	0.1	34
Macao SAR, China	359	3,915		0
Macedonia, FYR	1,294	1,272	0.3	14
Madagascar	18,718	1,377	1,043.2	3,488
Malawi	10,184	373	880.0	1,465
Malaysia	7,612	16,940	98.2	9,932
Mali	14,057	1,125	1,105.6	4,022
Malta	159	501	0.0	0
Mauritania	2,559	601	116.7	1,246

	Air Pollution $PM_{2.5}$		Water Pollution	
	Deaths	Welfare Loss	DALYS	Welfare Loss
	Number	USD$Mn. PPP	´000	USD$Mn. PPP
Mexico	26,484	37,709	300.9	19,472
Moldova	2,908	904	2.3	33
Mongolia	2,424	2,121	21.5	855
Morocco	7,034	3,723	185.8	4,471
Mozambique	12,525	659	813.3	1,945
Nepal	22,039	2,833	768.9	4,492
Netherlands	7,428	33,632	3.3	670
New Zealand	728	2,576	0.0	0
Nicaragua	1,578	490	51.3	724
Niger	13,609	583	2,002.7	3,900
Nigeria	97,248	37,609	9,124.6	160,400
Norway	337	1,990	0.8	223
Oman	655	2,619	1.6	297
Pakistan	156,191	47,713	2,957.9	41,072
Panama	524	912	13.3	1,051
Papua New Guinea	5,256	822	173.1	1,230
Paraguay	3,010	1,909	27.6	795
Peru	9,374	8,723	160.9	6,805
Philippines	57,403	26,758	877.9	18,601
Poland	23,295	61,626	3.3	400
Portugal	3,282	9,459	0.0	0
Qatar	110	1,178	0.7	324
Romania	15,880	26,658	3.6	274
Russian Federation	104,379	279,801	61.1	7,446
Rwanda	6,410	534	793.7	3,006
Saudi Arabia	6,285	30,246	27.1	5,924
Senegal	7,747	1,005	596.8	3,519
Serbia	4,627	5,029	3.9	190
Sierra Leone	5,284	553	721.4	3,432
Singapore	1,601	11,153	5.4	1,702
Slovak Republic	3,383	9,764	1.4	188
Slovenia	847	2,557	0.2	23
South Africa	19,802	20,656	587.2	27,842
South Sudan	9,966	1,115		0
Spain	14,689	49,331	6.8	1,038
Sri Lanka	19,693	16,336	73.2	2,762
Sudan	26,785	6,824	1,277.5	14,794
Sweden	1,329	5,809	1.4	287
Switzerland	3,016	15,910	1.1	272
Taiwan, China	16,739	71,685		0

	Air Pollution $PM_{2.5}$		Water Pollution	
	Deaths	Welfare Loss	DALYS	Welfare Loss
	Number	USD$Mn. PPP	´000	USD$Mn. PPP
Tajikistan	5,230	779	227.2	1,538
Tanzania	25,370	3,552	1,692.8	10,773
Thailand	48,819	63,369	262.0	15,461
Togo	4,123	292	241.4	777
Tunisia	3,792	3,308	32.3	1,279
Turkey	28,881	48,625	256.4	19,620
Turkmenistan	3,730	4,307	109.2	5,729
Uganda	20,658	1,927	1,376.5	5,836
Ukraine	49,078	31,631	14.6	427
United Arab Emirates	900	5,233	4.8	1,264
United Kingdom	19,803	76,694	0.0	3
United States	91,045	454,675	69.4	15,757
Uruguay	358	818	3.8	398
Uzbekistan	19,085	6,662	398.8	6,328
Venezuela, RB	5,738	12,229	87.5	8,472
Vietnam	66,314	23,832	605.7	9,894
West Bank and Gaza	1,006	309		0
Yemen, Rep.	13,442	3,229	807.6	8,818
Zambia	8,549	2,027	622.6	6,710
Zimbabwe	7,391	699	381.5	1,640
Total	**5,323,364**	**5,095,685**	**90,606**	**1,488,602**

AIR AND WATER POLLUTION

The losses due to air pollution have been studied in some depth by several researchers. The World Bank and IHME have recently summarized the findings in a report (World Bank-IHME, 2016) where they give the total deaths in 2013 due to concentrations of $PM_{2.5}$ and the welfare costs associated with these deaths. Table 3 summarizes the data from that report for 141 countries. Total deaths that would have been avoided if concentrations of this pollutant fell below WHO guidelines of $10\mu g/M^3$ are 5.3 million and the annual loss of welfare associated with those deaths is estimated at $5.1 trillion. Since these deaths would be avoided permanently, the stream of welfare benefits starting from 2030 discounted at 4 per cent would be $83 trillion. This measure of the natural capital gap reflects a target reduction of concentrations based on 2013 populations and 2013 concentrations. In 2030, both these numbers will have changed, so the gap measures would change accordingly. Further work is needed to estimate concentrations and populations exposed in the cities in that year in the absence of further measures.

In the case of water pollution, the WHO in its Burden of Disease calculations has estimated the loss of Disability Adjusted Life Years (DALYs) for almost all countries. Table 3 reports the available figures (which are for 2004 and hence rather dated) for the same countries as the World Bank data for air pollution. The valuation of a DALY is made based on the value of a saved life divided by 22, which is the recommended approximation suggested by the World Bank (Cropper and Khanna, 2014) on the assumption that on average the person whose life is saved would survive for 22 years. The value of an avoided death is taken from the air pollution calculations in that table. The gap is estimated at around $1.5 trillion.

In total, eliminating diseases due to water pollution, which is the 2030 target, would save 90 million DALYs with a welfare value of $1.5 trillion. Assuming these losses are eliminated from 2030 onwards, the discounted present value of the benefits is $24 trillion. As for air pollution, the size of the estimates for 2030 will differ from this as populations and exposure rates change. Further work is needed to make that calculation.

MATERIALS AND THE NATURAL CAPITAL GAP

According to the OECD, global primary materials use is projected to almost double from 89 gigatons (Gt) in 2017 to 167 Gt in 2060. Non-metallic minerals – such as sand, gravel and limestone – represent the largest share of total materials use. These non-metallic minerals are projected to grow from 44 Gt to 86 Gt between 2017 and 2060. Metal use is smaller when measured in weight, but is projected to grow more rapidly and metal extraction and processing is associated with large environmental impacts. (OECD, 2019). Table 4 shows changes in material use to 2060 as well as materials efficiency measured as GDP in constant USDPPP per ton of material. Growth in materials is expected to be less than growth in GDP, indicating an increase in efficiency. This is greatest for fossil fuels and biomass (around 2 per cent p.a.) 1.4 per cent p.a. for non-metallic minerals and least for metals (0.75 per cent).

Given the significant environmental impacts of material extraction and production, and scarcity of some minerals raising concerns that overuse could lead to future limits to growth, SDG 12 looks to increase materials efficiency even further. UNEP and the International Resources Panel (IRP) have published a Global Resources Outlook (UNEP, 2019), in which they claim that “concerted resource-efficiency and sustainable resource-management measures can reduce resource extraction by 25 per cent, significantly mitigate negative impacts and boost the economy by 8 per cent by 2060.” (UNEP, 2019). The 25 per cent reduction is relative to an historical trends scenario that has a total of 187 Gt in 2060, with a different breakdown between the four categories of materials from the OECD study. They further claim that the historical trends projected increase to 2060 “would result in substantial stress on resource supply systems and in higher levels of environmental pressures exceeding the safe operating spaces for society and companies.” (UNEP, op. cit.).

The relationship between reduced use of materials and the natural capital gap is complex, as noted earlier. Three sources of value of natural capital associated with reducing the use of such materials were: a reduction in the loss of ecosystem services by having less impact on the environment; more materials being available for future generations to use, the value of which should be based on the scarcity rent of the current extraction; and an increase in GDP brought about by creating innovation and developing new areas of economic activity related to materials recovery. On the first of these there are no data to value the reduced damages from less materials recovery accurately. Various studies on the costs of environmental degradation give estimates in the range of 2–8 per cent of GDP and it is likely that for materials the costs will be in this range as a per cent of total value of output. Hence, indicative estimates have been made on that basis. With regard to scarcity rents, research done some time ago shows that such rents only amount to a significant amount when expected reserves are less than a few decades worth or current extraction (Farzin, 1992). There are hardly any minerals for which this is the case and so no scarcity rents have been included. Lastly, evidence for higher growth as a result of a more efficient resource use policy, as suggested in the UNEP/IRP report is very limited. It is not considered credible enough to be included in the valuation of the natural capital gap.

Table 4: Projections for Materials Use to 2060

					Growth Rates P.A.	
		2017	2030	2060	2017-2030	2017-2060
Historical Trends	Biomass Gt	21.53	25.63	37.14	1.35%	1.28%
	Fossil fuels Gt	14.79	17.39	24.12	1.25%	1.14%
	Metals Gt	8.63	11.87	19.52	2.48%	1.92%
	Non-metallic minerals Gt	43.86	55.73	86.22	1.86%	1.58%
	World GDP at Constant PPP USD Trillion	115.21	174.56	373.41	3.25%	2.77%
	Material Efficiency (USD/t)					
	Biomass	5,351	6,811	10,054	1.87%	1.48%
	Fossil fuels	7,788	10,035	15,482	1.97%	1.61%
	Metals	13,351	14,711	19,133	0.75%	0.84%
	Non-metallic minerals	2,627	3,132	4,331	1.36%	1.17%
Toward Sustainability Scenario	Biomass Gt	21.53	24.36	32.00	0.95%	0.86%
	Fossil fuels Gt	14.79	13.10	8.00	-0.93%	-1.53%
	Metals Gt	8.63	9.24	9.37	0.52%	0.05%
	Non-metallic minerals Gt	43.86	55.73	86.22	1.86%	1.47%
	Material Efficiency (USD/t)					
	Biomass	5,351	7,166	11,669	2.27%	1.83%
	Fossil fuels	7,788	13,324	46,676	4.22%	4.25%
	Metals	13,351	18,898	39,860	2.71%	2.58%
	Non-metallic minerals	2,627	3,132	4,331	1.36%	1.17%

Sources: OECD (2019), UNEP (2019).

In making the estimates reported here, the following assumptions have been made on the projections from the two sources and on the valuation of minerals:

- Biomass use can be reduced from the OECD estimate of 37Gt to the UNEP/IRP target of 32Gt by 2060.
- Fossil fuel use can be reduced from the OECD estimate of 37Gt to the UNEP/IRP target of 8Gt by 2060.
- Metal use can be reduced from the OECD estimate of 19.5Gt to the UNEP/IRP target of 9.4Gt by 2060.
- The non-metallic minerals target for 2060 are the same in the OECD and UNEP/IRP projections so no change is expected there.
- Changes in intervening years to 2060 are in proportion to the changes for 2060.
- Values of different materials are a weighted average of latest prices, with weights based on current quantities.

The natural capital gap is presented in Table 5. As mentioned earlier, it is the present value of the reduction in ESS losses on account of the lower extraction and use of raw materials. The reductions taken into account are only those to 2030 as that is the date for the SDGs. Once savings have been set up, the benefits will flow for future years beyond 2030 and that has been taken into account. The gap is estimated at between $2.6 and 10.4 trillion, based on the UNEP Towards Sustainability Scenario.

Table 5: Natural Capital Gap from Meeting Improved Material Efficiency Targets (USD Billion)

Material	Lower Bound	Upper Bound
Biomass	176	705
Fossil fuels	810	3,242
Metals	1,617	6,467
Total	**2,603**	**10,413**

Source: Own calculations

GHG EMISSIONS AND THE NATURAL CAPITAL GAP

The Paris Agreement, adopted by the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 2015, entered into force in 2016. The agreement established a process for moving the world toward stabilizing greenhouse gas (GHG) concentrations at a level that would avoid dangerous climate change. According to the UN Emissions Gap Report, emissions of GHGs in 2017 were 53.5 $GtCO_2e$. They need to be 25 per cent and 55 per cent lower in 2030 than in 2017 to put the world on a least-cost pathway to limiting global warming to 2°C and 1.5°C, respectively (UNEP, 2018). Under current policies, emissions are expected to be around 59 $GtCO_2e$ in 2030. Hence, the reduction in emissions to be reached in 2030 relative to where they would be under current policies is 18.9 Gt for the 2°C target and 34.9 for the 1.5°C target. To get to these targets by 2030, a progressive reduction will be required over the next 11 years. It is assumed that these reductions will increase at a constant rate to get to the 2030 target values.

The annual reduction in emissions over the period to 2030 is valued using the social cost of carbon (SCC). The SCC values are based on the discounted costs arising from a tonne of CO_2 over the long term and therefore are sensitive to the discount rate adopted. The higher the discount rate the lower will be the value attached to future costs and hence the lower will be the discounted present value of the costs. The discounted values also increase over time as costs rise with higher levels of GHGs in the atmosphere. The elements in the SCC are explained in Box 1 below, taking the discussion from the US government review of SCC (US Government, 2013). Based on a review of different models to estimate damages, the document gives a range of \$11–52/tonne CO_2 in 2015, rising to \$16–76/tonne CO_2 in 2030 (in US\$ 2007). These values have been converted to US\$ 2019 prices in the calculations reported below.

Box 1: Elements in the social costs of carbon

The social cost of carbon (SCC) is calculated by running an Integrated Assessment Model (IAMs) in which future economic output is estimated under different scenarios for emissions of GHGs. By running the model with a given emissions scenario, calculating the discounted present value of output and then running the model again with a small increase in emissions in the current period a second discounted present value is obtained. Subtracting the discounted value in the second run from the first gives an estimate of the cost caused by that small increase is arrived at. Dividing the cost by the change in emissions gives the SCC today. The same calculation can be made starting the model in 2020, 2030 etc. to get the SCC for that year.

The impacts of climate change taken into account vary from one model to another. Three major models are DICE, FUND and PAGE. All include the cost caused by sea-level rise, agriculture and energy (higher demand for energy for cooling but less for heating). These also include additional costs of health treatment resulting from higher temperatures and extreme events. Models vary in the cost function they use (i.e. the link between emissions and climate change and between climate change and costs) and there is an element of arbitrariness about the functions. Elements not included in the models are:

1. **Incomplete treatment of non-catastrophic costs:** current IAMs do not assign value to all important physical, ecological and economic impacts of climate change, and it is recognized that even in future applications a number of potentially significant cost categories will remain non-monetized, i.e. ocean acidification (not quantified by any of the three models), species and wildlife loss.
2. **Incomplete treatment of potential catastrophic costs:** cost functions may not capture the economic effects of all possible adverse consequences of climate change, i.e. potentially is continuous "tipping point" behaviour in Earth systems; inter-sectoral and inter-regional interactions, including global security impacts of high-end warming; and imperfect substitutability between cost to natural systems and increased consumption.
3. **Uncertainty in extrapolation of costs to high temperatures:** estimated costs are far more uncertain under more extreme climate scenarios.
4. **Incomplete treatment of adaptation and technological change:** models do not adequately account for potential adaptation or technological change that might alter the emissions pathway and resulting costs.

Source: US Government (2013)

The value of the reductions in emissions is shown in Table 6. They can be interpreted as the natural capital gap arising from levels of GHGs in the atmosphere that reduce a range of services.

If emissions reductions consistent with the 2°C target are met to 2030 the present value of the natural capital services provided is between $1.6 trillion and $7.7 trillion. With the 1.5°C target, the reduction in emissions is greater and the consequent value of the natural capital services is between $3.3 trillion and $15.3 trillion. These ranges would be even greater if the full range of SCC values was included. Some of the very high SCC values, however, are speculative and need more research to determine their validity.

Table 6: Natural Capital Gap Arising from the Gap in GHG Emissions (USD Trillion)

Scenario	Lower Bound	Upper Bound
Target of 2ºC Stabilization	1.6	7.7
Target of 1.5ºC Stabilization	3.1	15.3

CLIMATE-RELATED HAZARDS, NATURAL DISASTERS AND THE NATURAL CAPITAL GAP

According to the Centre for Research on the Epidemiology of Disasters (CRED), deaths from natural disasters globally in 2017 were 9,697, of which 6,365 were climate related (i.e. arising from drought, extreme temperature, flood, storm or wildfire). Since annual figures are subject to random fluctuations, a better indicator is the average annual number over the past decade (2007–2016), which was 3,220. The number of people affected by climate-related disasters in 2017 was 91.9 million while the average annual number over the previous ten years was 19.9 million. In what follows, the average over the 11 years (2006–2017) is taken as indicative of current rates of impact of climate-related disasters. The corresponding figures are: average deaths 6,668 deaths and 26.4 million people affected.

SDG 13.1 has a target of reducing the impact of climate-related hazards, but does not give a numerical target. Given the strong targets on eliminating deaths from water pollution, it would seem reasonable to aim for a significant reduction here. Hence, an 80 per cent reduction by 2030 is taken as a plausible target.

In valuing the benefits of such a reduction, the cost per life saved is based on the global average in the World Bank-IHME study of $957,230. This is the figure arrived at by dividing the total welfare loss by the number of deaths for the latest year for which data are available. In the case of people affected, costs in terms of health are taken as 10 per cent of costs of mortality.[9] In addition, there are economic losses associated with the people affected. CRED provides estimates of these, which come out at $1,445 per person affected.

The value of reducing the losses by 80 per cent by 2030, beginning in 2020 and working gradually up to the target in equal steps, provides a benefit of $12.3 trillion. This is made up of avoided deaths (0.2 per cent), avoided impacts on persons affected (98.3 per cent) and economic losses avoided (1.5 per cent). It needs to be recognized, however, that not all these benefits can be attributed to natural capital. While reducing emissions of GHGs in accordance with the 1.5°C and 2.0°C targets will reduce natural disasters, as will enhancing the resilience of natural capital such as coastal lands, a good part of the target will require investment in physical capital as well, such a dykes and other barriers. The role of natural capital will come in enhancing beaches in the case of sea-level rise and storm surges, accommodating such events by setbacks and increasing the resilience of agriculture to droughts and other extreme events.

In the case of sea-level rise the role of natural capital-type solutions is estimated by UNFCCC at around 23 per cent of the total cost of all capital investments (UNFCCC, 2007). A figure for the overall share of natural capital is not available. As an indicative value it is taken to be between 25–35 per cent of all measures to deal with climate related disasters. This gives a range for the natural capital gap related to this item as $3 trillion to $4.3 trillion.

PROTECTED AREAS, FORESTS AND THE NATURAL CAPITAL GAP

The target year in the SDGs for losses of terrestrial and freshwater inland ecosystems is 2020, but that is obviously unrealistic, so 2030 has been adopted as the target date. In addition, the reduction of losses is not specified in the SDGs, but they are stated in Aichi Targets that were adopted as part of the Convention of Biological Diversity's Strategic Plan for Biodiversity 2011–2020. The Aichi targets are closely related to the SDGs, hence it is reasonable to take them as the appropriate ones. The relevant ones for this exercise are halving of the rate of loss of forests and wetlands, and ensuring that at least 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services. These are conserved through effectively and equitably managed ecologically representative and well-connected systems of protected areas and other effective area–based conservation measures and integrated into the wider lands.

The value of the increase in natural capital associated with these targets has been determined (calculations are adapted from Markandya, 2015) as follows:

9 This 10 per cent estimate is based on an OECD review of such costs relative to mortality costs (Hunt *et al.,* 2016).

Forests

Markandya and Chiabai (2013) estimated the value of the physical losses of boreal, temperate and tropical forests under a business as usual scenario. The physical data were taken from the extensive work of Aklemade *et al.,* 2006, who calculated losses if no further actions were taken for the period 2000–2050. These physical losses are estimated at 9 per cent of 2000 boreal forest stocks, 19 per cent of temperate forest stocks and 12 per cent of tropical forest stocks. The losses were then valued using studies of the commercial and fuel wood values of timber, recreational values for forests, passive values (i.e. the values of those who are willing to pay for forest to be conserved in addition to paying for those services they do use), and carbon storage values of forests. Taken together, these give the total value for the whole period.

As expected, the study comes up with a range: the lower bound is $334 billion per year while the upper bound is $1,118 billion, or over three times as much. Here these estimates have been taken. It is further assumed the losses are uniform over the time period 2000 to 2050 and the figures updated to US$ 2019 dollars. It is further assumed that: as per the target, 50 per cent of the losses will be arrested as a result of the programme; the benefits in terms of reduced losses will start appearing in 2027 when the programme, which will start in 2019 is complete; and the benefits will continue to 2050. The present value of the resulting benefits discounted at 4 per cent range between $3.8 trillion and $12.7 trillion.

Wetlands

In the case of wetlands, the calculation is more difficult. Current areas are even more uncertain than they are for forests and services provided vary significantly by location. The present estimates are based on the following assumptions:

- The current stock of wetlands is divided into inland and coastal, with the latter including mangroves. Areas were taken from the Global Lakes and Wetlands Database, developed through a partnership between World Wildlife Fund (WWF), the Centre for Environmental Systems Research and University of Kassel, Germany. From their figures—which are global—lakes, rivers, freshwater marshes/flood plains and swamp forests were taken as inland wetlands, and those defined as coastal and saline wetlands (including mangroves) as coastal.[10] The respective areas in 2010 were 1,061 million hectares for the former and 152 million hectares for the latter.[11]
- Estimates of rate of loss from a number of sources, is put at around 0.7 per cent per annum for both types of wetlands (Finlay and Spiers, 1999).
- The services provided by different wetlands have been synthesized in a number of studies, of which perhaps De Groot *et al.* (2012) is one of the most extensive. Those included in the studies reviewed cover provisioning (food, water, raw materials, etc.), regulating (climate regulation, water flow, erosion prevention, etc.), habitat (nursery and genetic diversity) and cultural (recreational use, spiritual experience, etc.). In total, 139 studies of coastal wetlands and 168 studies of inland wetlands studies were carefully analysed to provide a range of benefits in US$/ha/year. The ranges vary widely: for freshwater wetlands, the lower bound (in US$ 2007) is about $3,000/ha/year and the upper bound is $105,000/ha/year. Likewise, the ranges for coastal wetlands range from $37,000/ha/year to $888,000/ha/year.
- The benefit figures were updated to 2019 prices so the benefits could be compared. The target programme that is valued is expected to reduce loss rates by 50 per cent, starting from 2027 (it takes about seven years to implement the programme). The present value of resulting benefits discounted at 4 per cent is between $0.1 trillion and $7.8 trillion.

10 http://www.worldwildlife.org/science/data/item1877.html. Accessed 12 June 2014.

11 This still leaves a number of areas that are ambiguous but that would have some wetland function. Excluding them could underestimate the area of wetland by as much as 30 per cent.

Protected areas

Target 11 aims to increase protected areas to 17 per cent of terrestrial land area and 10 per cent of coastal and marine areas by 2020. According to the Strategic Plan for Biodiversity (CBD, 2012a), there are currently some 13 per cent of terrestrial areas, 5 per cent of coastal areas and very little open oceans under protection. Therefore, reaching the proposed target implies a modest increase in terrestrial protected areas globally, but most importantly with an increased focus on representativeness and management effectiveness, and with major efforts to expand marine protected areas. Protected areas should also be established and managed in close collaboration with, and through, participatory and equitable processes that recognize and respect the rights of indigenous and local communities, and vulnerable populations.

The closest estimate of the benefits of the increase in terrestrial area is in the TEEB-related study of Hussain *et al*. (2011). It analyses a slightly different expansion: of 20 per cent by 2030, but from their annual benefits and costs of the programme, one can make an estimate of the corresponding costs and benefits for the target programme. It is assumed, as they do, that 10 per cent of all eco-regions of the world were protected in 2000, giving a total protected area of 13.2 million km^2 (i.e. the same as the CBD estimate), but that this figure had increased to 14.7 per cent of land area and 10 per cent of territorial waters by 2016, putting the world on track to meet this major global conservation.[12] The remaining increase left to be made in 2016 therefore was 3.17 million km^2. This is assumed to take place over the period 2017–2020, thus fulfilling the SDG goal.

In terms of benefits, Hussain *et al*. (op. cit.) estimate the biophysical changes resulting from the protection and value the ecosystem services that such a change provides. The areas that increase in most parts of world include grassland and forest, but in some cases protected areas are created by reducing land from these biomes as well. They provide estimates of the services gained into two groups: those related to the capture of carbon and the rest. The reason is that the former has, in their view, much greater uncertainties and are global benefits, while the rest are, in large part, local benefits. The benefits are then reported as a lower bound (without carbon storage benefits) and an upper bound (with carbon storage benefits).[13] The resulting benefits amount to between $123 billion and $210 billion, indicating that the natural capital gap here is relatively small.

12 https://www.iucn.org/theme/protected-areas/our-work/quality-and-effectiveness/world-database-protected-areas-wdpa.

13 The carbon benefits are estimated on two bases: first from models in which a carbon target has been set and in which one can calculate the cost per ton reduced; and second from models that estimate the damages done per ton emitted via climate change. See Hussain *et al.,* 2011 for details.

6. SUMMARY OF ESTIMATES OF THE NATURAL CAPITAL GAP

A summary of the estimates for the different components of the natural capital gap in relation to the SDGs is given in Table 7 and Figure 2 as shares of the total. The sum of what could be estimated is between $31.9 trillion and $86.9 trillion, with the largest uncertainties arising from the value of remediating land, reducing forest loss and reducing loss of wetlands. In relative terms, the largest share is related to land remediation. The second largest share depends on whether the lower bound or the upper bound is taken. With the former, it is reduced air pollution, followed by less deforestation and reduced losses from climate-related disasters. With the latter, the second largest share is the reduction on GHGs, followed by less deforestation and reduced use of materials.

One can compare this natural capital gap with the stock of natural capital as estimated by the World Bank (Lange *et al.,* 2018), which puts the value at about $105 trillion globally. This analysis suggests that meeting these SDGs could enhance that stock by between 30 per cent and 83 per cent.

There are a number of policy implications from this preliminary assessment of the natural capital gap. One is to concentrate attention on the way in which meeting the SDGs entails increasing the stock of natural capital. Of course carrying out the programmes will require physical and human capital resources, and this should be done in a cost efficient manner, but the targets themselves are agreed as social goals and not subject to a cost benefit analysis.

Ways in which a capitals approach can be applied to evaluating individual programmes are discussed in the next sections. The local programmes contribute to the national targets but selecting between them needs some further considerations that are discussed in these sections.

The second is to provide some guidance to businesses on how natural capital methods can help mainstream their aims of contributing to the SDGs. Estimates of measures they take to reduce material use, reduce emissions to air and water, as well as lowering greenhouse gas emissions, can all be measured and interpreted as contributing to an increase in the value of natural capital. The methods described here can be applied at the enterprise level to make those estimates, which can be reported along with other performance indicators.

The methods described here need further development. Scientists, modellers and policymakers need to work together to improve estimates of natural capital and demonstrate its links to the green economy and to climate policy.

Table 7: Value of the Natural Capital Generated by Meeting the SDGs (USD_{2019} Trillion)

Source of Gap	Services Provided	LB*	UB**
Degraded land	ESS from land remediation	13.7	29.6
Air pollution	Reduced health damages from cleaner air	5.1	5.1
Water pollution	Reduced health damages from cleaner water	1.5	1.5
Reduced materials	Reduced damages to ESS	2.6	10.4
GHG emissions	Reduced damages from less climate change	1.6	15.3
Climate-related disasters	Less climate-related disasters and less damages from disasters	3.0	4.3
Coastal & marine areas	Loss of ESS associated with these areas	n.e.	n.e.
Forest loss	Timber, non-timber, carbon, amenity and non-use services from reduced loss of forests	3.8	12.7
Wetlands	Services include: Provisioning (food, water, raw materials, etc.), Regulating (climate regulation, water flow, erosion prevention, etc.), Habitat (nursery and genetic diversity), and Cultural (recreational use, spiritual experience, etc.)	0.1	7.8
Protected areas	Biodiversity and amenity benefits less losses from use for agriculture	0.12	0.21
Total		**31.9**	**86.9**
As % of World Bank estimate of natural capital		30.3%	82.7%

**LB*: Lower Bound ***UB*: Upper Bound

Source: Own calculations

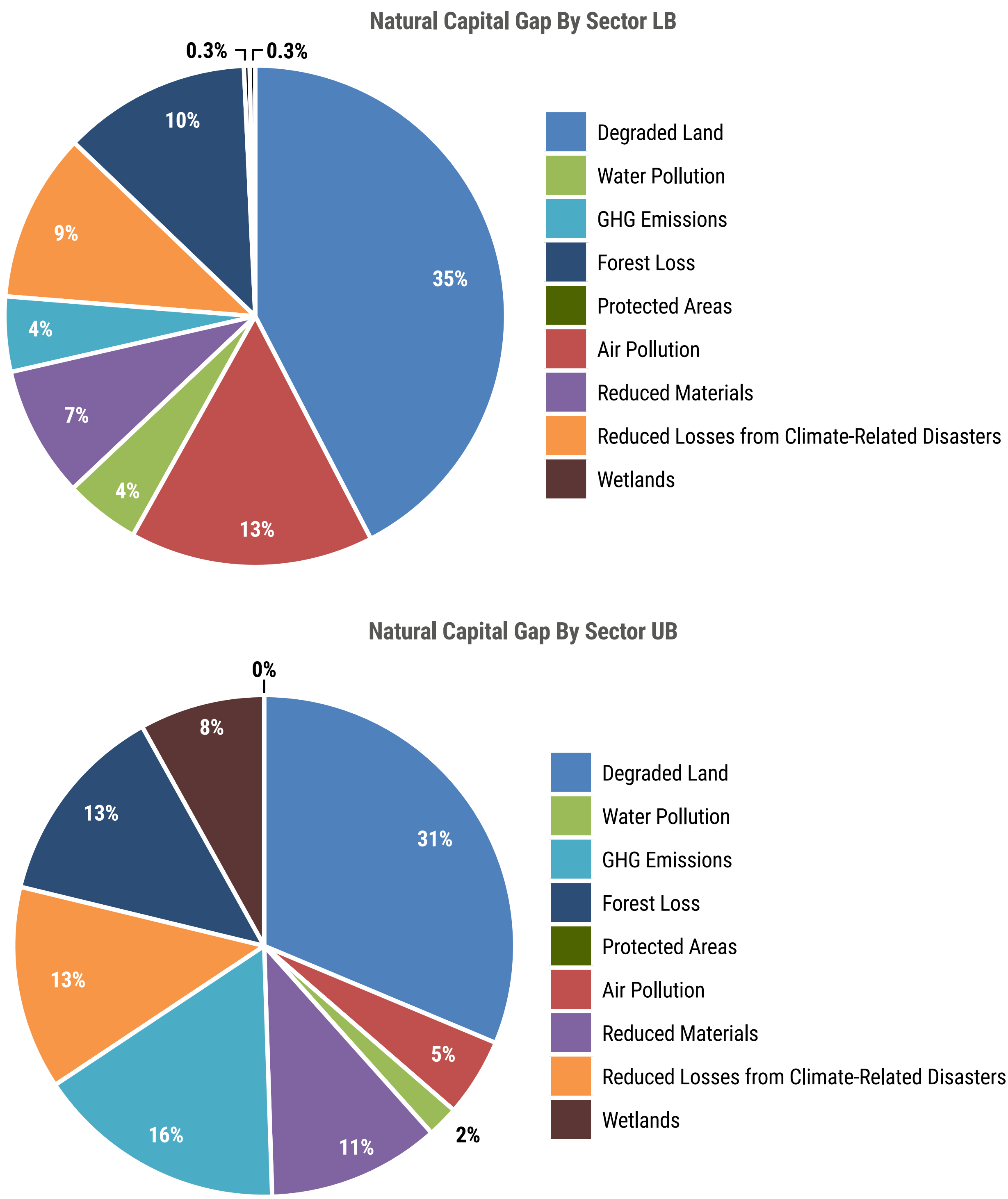

Figure 2: Natural Capital Gap by Area of Impact

7. A CAPITALS APPROACH TO EVALUATING PROJECTS AND PROGRAMMES FOCUSING ON IMPROVING ECOSYSTEM SERVICES

Programmes that address the degraded state of the environment and seek to remediate it can be characterized in terms of flows of good and services, or in terms of changes in stocks. Both methods can be used to link them to the SDGs, but the one based on stocks is possibly better suited to tracking the impacts of such programmes in terms of their impacts on the SDGs.

As an example, a programme covering a tract of degraded land will require investment in remediation, as a result of which it will become more productive and generate a flow of income, net of the costs of production, greater than it was able to do before the remediation. The same programme will also have a range of co-benefits. People dependent on the land for a living will have higher incomes, reducing the chances of them being classified as poor. They will also be less likely to face hunger, especially in places where food consumption is mainly tied to own production. Other co-benefits could include an improvement in non-commercial fauna and flora, an increase in biodiversity, less erosion and greater water retention.

An evaluation of the programme can be made by matching these benefits relative to the investment required to remediate the land. Conventional cost-benefit analysis would simply compare the investment costs against the flow of increased benefits, taking account of any price distortions due to subsidies and taxes in the prices of inputs and outputs. Where farm outputs were not sold in markets, an implicit market price would be used, and where labour on the project was previously underemployed this would be taken into account by applying a “shadow wage” to it in the calculations of costs and benefits. Other non-monetary benefits such as reduced hunger and poverty would not be valued, but might be given consideration in the overall assessment of the benefits of the programme.

Under the capital approach proposed here, land with differing degrees of degradation has different values as a form of natural capital. The programme can then also be seen as increasing the stock of that capital, but by taking resources that could otherwise be used to add to the stock of physical capital. Thus, the programme increases one stock of capital at the expense of another. In addition, the remediation programme also increases the stock of human capital (better fed people are more productive and high employment increases the value of human capital), the stock of social capital (where there is less poverty, people are able to interact more and participate in social institutions) and the value of physical capital by making it more productive. These changes can also be valued in money terms (although valuing social capital is difficult) and the net changes in different forms of capital compared.

It could be argued that a capital approach is better for two reasons. One arises from the fact that one is dealing with restoration of a key form of capital – natural capital – that has a unique function in the ecological-economic system. It has been argued, for example, that loss of some forms of natural capital cannot be compensated for by an increase in physical capital and that at least some of the SDGs seek to ensure that a given stock of natural capital is maintained. The capital method allows the analyst to calculate the cost of increasing the stock of natural capital to meet a given SDG target and to choose between alternative programmes that remediate a given stock of degraded land. In this respect, it is not a cost-benefit analysis but a cost-effectiveness analysis. Second, the so-called ancillary benefits of remediation can also be converted into an increase in a form of capital and the programme evaluated holistically, taking account of changes in physical, natural, human and social capital.

Figure 2 lays out the two approaches and how they are linked to one another.

The capital approach would compare different alternative measures that increase the stock of natural capital by a given amount. That amount could be tied to a threshold value, considered necessary to maintain an ecosystem's integrity, or an increase that is meeting some developmental goals, such as those given by the SDGs. The selected option would be the one that meets the threshold or other values while giving the greatest increase in the net stock of all capitals.

The analysis in terms of flows could conclude that the project is not justified in terms of net benefits, if these turn out to be less than zero. This can be the case if some benefits cannot be measured, or if the value of agriculture (commercial plus self-consumption) is very low as measured using conventional techniques. The capital approach, however, will evaluate the options from a different criterion. An increase in natural capital is an objective in its own right. The analysis looks at the net change in other capitals for different ways of attaining the given increase in natural capital. Other things being equal, the option that gives the largest net increase in all capitals, or that gives a given increase in natural capital at least cost in terms of other capitals, is the preferred one.

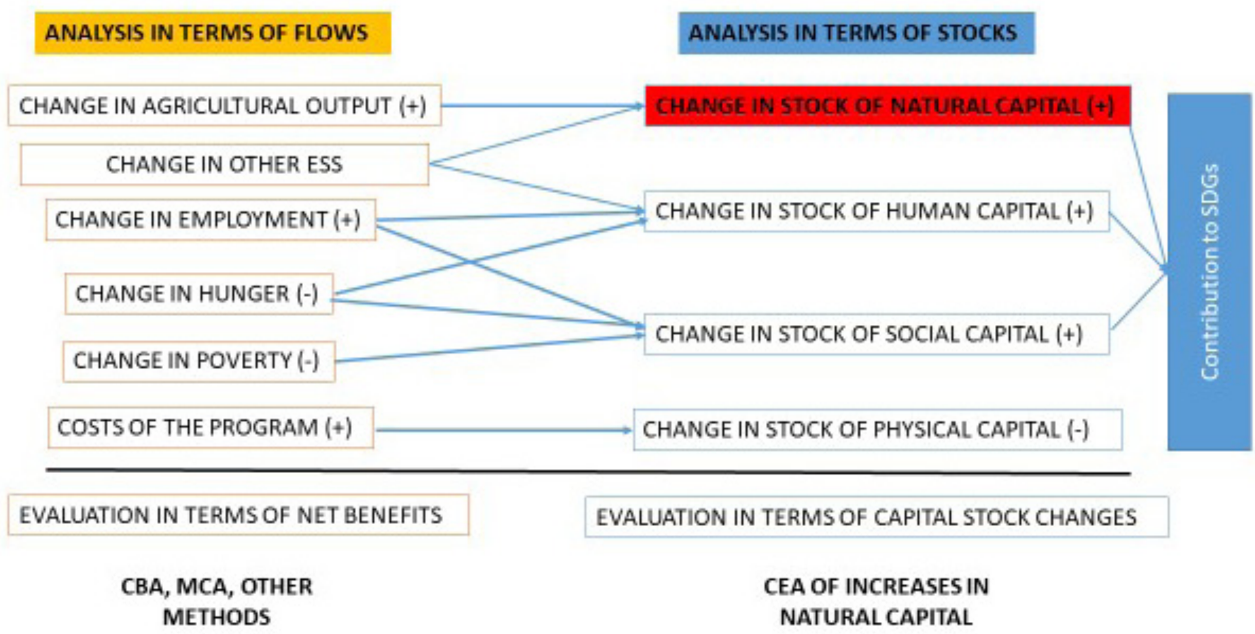

Figure 3: Flow and Stock Analysis

8. APPLICATION OF THE CAPITALS APPROACH

Three studies are being undertaken where the capitals approach can be considered and compared to the more conventional cost-benefit approach. One is for three districts of the state of Madhya Pradesh in India where there has been an ongoing programme of land remediation and cost estimates of the investment required to remediate it have been made. Baseline information on employment, rural wages, poverty and hunger are also available. Impacts of remediation are being made by comparing performance of areas under the programme against control villages where there has been no programme. Based on these estimates of the changes in net benefits (the conventional approach) are compared with an analysis of the changes in capitals achieved as a result of the programme and of their contribution to the SDGs. Ranges will be used to take account of uncertainties in productivity changes and underlying trends in poverty, hunger, etc. The results are of interest to the Government of India, which is seeking to expand it programme of land remediation.

A second study is taking place in the Kyrgyz Republic where a national-level assessment is being undertaken on the potential benefits of remediation of degraded pasture lands. The present analysis will follow the GIZ Economics of Land Degradation (ELD) protocols to conduct a cost-benefit analysis to justify different interventions. A secondary assessment that is under consideration is to estimate the increase in the value of natural capital and other capitals the programmes generate, compare the relative contributions of different programmes if possible, and measure their performance in terms of its contribution to the SDGs.

A third study is for Rwanda. It is also a national assessment with strong government support. The approach taken is different, based on calculating the benefits of different remediation programmes using a computable general equilibrium model that also calculates the impacts of the programmes on a number of SDGs. The aim here will be to see how the analysis can be viewed and presented in terms of different capitals and a comparison between them made on that basis.

9. CONCLUDING REMARKS

This paper has laid out two important uses of a natural capital approach in policies related to economic and social development. The first is to estimate a natural capital gap with respect to key SDGS that are linked to the state of the natural resource base. The gap would measure the extent to which different components of natural capital have to be increased to meet these SDGs. The gap can then be the focus of action plans to increase natural capital in the most cost-effective way.

The second is to use a natural capital approach to appraise programmes aiming at restoring natural capital. This could be used in parallel with the more conventional cost-benefit approach, but with a focus on looking at different ways in which a given increase in natural capital can be achieved.

Preliminary estimates of the gap are provided at the global level for a range of SDGs and at the national level for land degradation, air and water pollution.

The next step in the work is to make a more detailed analysis of the gap at the national level and firm up some of the provisional figures used here. The gaps can then be compared with the costs of eliminating them in the most cost-effective manner. This will also provide an indication of where scarce resources should be used to eliminate different components of the natural capital gap.

In the case of the appraisal of projects aimed at restoring natural capital, the detailed case studies for land remediation in central India, Kyrgyz and Rwanda will provide applications of the different approaches to evaluating remediation in a benefit cost approach and comparing them with a capitals approach linked to the SDGs.

ANNEX I: SDGS TARGETS PROPOSED INDICATORS AND LINKS TO NATURAL CAPITAL

	SDG Targets	Proposed Indicators	Link to Natural Capital
2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	Per cent land under productive and sustainable agriculture; nutrient balance (N), (P)	Local/national; not global
2.5	By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed	Per cent of local breeds at risk of extinction	Local/national/global
3.9	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Mortality rates due to air and water pollution	Local/national/global
6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Per cent of households not connected to treated wastewater	Local/national; not global
6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	Freshwater withdrawal as a per cent of available freshwater	Local/national/global
8.4	Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries	Material footprint per unit GDP Material consumption per Unit GDP	Local/national/global

	SDG Targets	Proposed Indicators	Link to Natural Capital
9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	Emissions CO_2 per unit GDP	Local/national/global
11.6	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management. (Link to 3.9)	Annual mean levels of $PM_{2.5}$ in cities weighted by population	Local
12.2	By 2030, achieve the sustainable management and efficient use of natural resources	Material footprint per unit GDP Material consumption per unit GDP	Local/national/global
13.1	Combat climate change and its impacts. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Number of deaths, missing persons and persons affected by disaster per 100,000 people	National/global
14.1	By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information.	Per cent of conserved areas	Local/national/global
15.1	By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	Forest area as per cent of all land area Per cent of sites for biodiversity that are protected	Local/national/global
15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	Net deforestation reduced to zero	Local/national/global
15.5	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Rate of loss of biodiversity	Local/national/global

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