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Biodiversity and ecosystem services in environmental profit & loss accounts

A working paper by Dr Becky Chaplin-Kramer, Lead Scientist, Natural Capital Project and Dr Jonathan Green, Postdoctoral Researcher, Cambridge Institute for Sustainability Leadership

Acknowledgements

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We operate as a partnership between Stanford University, the University of Minnesota, The Nature Conservancy, and World Wildlife Fund. We are a team of academics, software engineers, and real-world professionals with the optimism, commitment, and humility to work together to effect change.

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Working papers

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Abstract

The Environmental Profit & Loss (EP&L) methodology, a pioneering corporate natural capital accounting methodology, was developed at Kering to help corporate decision-makers understand environmental impacts in their business and supply chains. Several companies are now mainstreaming the EP&L as an internal decision-making tool, and it is included as a methodology within the Natural Capital Protocol (NCC 2016). Kering is committed to continuous improvement on the EP&L methodology and as such has focused efforts on how to better represent impacts on of biodiversity and ecosystem services at the base of the supply chain where raw materials are produced and sourced. This report provides recommendations and examples of how the EP&L can be adapted into a more flexible and cutting-edge tool, but the findings are more generally relevant for measurement of a company's impacts on natural capital, whether through an accounting-based framework or not.

The first set of recommendations are aimed at enhancing the current EP&L approach, through spatial, predictive modelling for ecosystem services and utilising a growing platform of global data and models on natural capital. Our proof-of-concept analyses have shown that current EP&L assessments may be underestimating the impacts of agricultural management on biodiversity and ecosystem services by 2–5 times. The second set of recommendations involves aspects of biodiversity that are currently missing in the EP&L, and the consideration of an additional indicator for biodiversity that can sit alongside. Together, these recommendations provide scope for work that will allow the EP&L and accompanying indicators the flexibility to explore new management scenarios and test possibilities for companies to have positive impact in the production process.

These next-generation approaches for and beyond the EP&L will represent the most current data and understanding of the spatially explicit ecosystem dynamics occurring in land-use impacts for the raw material stage of production, providing companies with better estimates of natural capital risks and opportunities.

1 Introduction

Understanding the impact that a commodity supply chain, a product, a consumer unit, a company or a brand has on biodiversity and ecosystem services is essential, both because companies are a globalising force that can make more rapid progress toward sustainability than many other actors (O'Rourke 2014), and because the corporate footprint has grown so large that the risk of catastrophic decline in natural capital resulting from poor stewardship is too great to ignore (Kareiva et al. 2015). Such declines can impact businesses and brands directly through increasing costs of raw materials and scarcity of supply, or indirectly through damage to brand reputation or increased difficulty in obtaining a licence to operate (Cranston et al. 2015). Corporate decisions will affect how, when and where business depends upon, impacts, and supports biodiversity and ecosystem services. If businesses are to become more sustainable, decision-makers will need accurate assessments of where dependencies and impacts are most significant and, consequently, where in their supply chains businesses can leverage the most appropriate solutions to reduce or eliminate ecosystem degradation. It was within this context of concern that Environmental Profit & Loss Accounting (EP&L) was developed to provide insight into the impacts of a business and its supply chains on biodiversity and ecosystems, and to guide decisions about how to reduce or avoid the impacts.

Biodiversity is the variability among living organisms from all sources (CBD 1992, Article 2). Its abundance, distribution and variability are all important and can be measured at a variety of levels, from genes, through species and populations, to ecosystems (Mace 2005). Biodiversity is vital to the functioning of our ecosystems and it can be viewed as a 'stock' of natural capital, from which a wealth of 'ecosystem services' flow (Bolt et al, 2016). These services are the benefits nature provides to humans, including harvesting of wild meat; pollination of food crops; and regulating services that maintain our air and water quality (Hassan et al, 2005). Biodiversity also directly affects human wellbeing through recreational, spiritual, and other cultural values. Finally, biodiversity has value to people just by its existence. The focus of this report is to consider ways to enhance the representation of biodiversity and related ecosystem services values in the EP&L.

1.1 Environmental Profit and Loss Accounting

The EP&L aims to place a financial value on the environmental impacts of a company: for example, the cost of a reduction in water quality when industrial processing of a raw material pollutes local water supplies. In doing so, the EP&L framework provides a currency metric to allow a comparison of the cost of impacts across a disparate range of environmental impacts and in a language that resonates with private sector decision-makers (Kering 2015a). It also allows comparison between the performance of a business according to traditional accounting systems and to the cost of its environmental externalities. In 2011, Kerring and PUMA published the first ever EP&L as the first pilot, which has since been expanded, improved and rolled out across all the Kering brands.

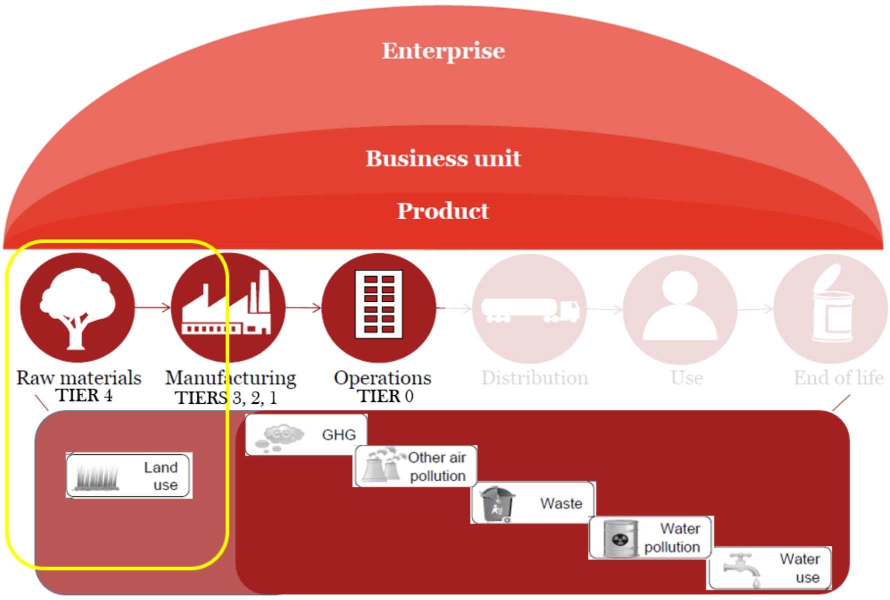

Figure 1: The Environmental Profit & Loss (EP&L) Framework. ***An EP&L measures and values the environmental impacts borne by society as a result of a business's activities. This ultimately helps a business to understand and manage its impact on natural capital across the supply chain. It uses six major groups of environmental impact: greenhouse gas emissions, water consumption, waste, water pollution, air pollution and land use***

Biodiversity and ecosystem services can be impacted across the whole chain of business operations (Figure 1): at the site of raw material production; during manufacturing, processing and transport processes; in activities of direct operations or retail sites; and in the way that products are used by consumers and disposed of at the end of their life (Aiama et al. 2016; Vallejo & Cassan-Barnel 2014).

Kering uses its EP&L to measure impacts across operations, manufacturing, and raw materials (Figure 1: Tiers 0 to 4), and this has demonstrated that Kering's impact on the environment is largest during the production of raw materials. This is due to the large areas of land affected by the production or harvest of raw materials as well as the resulting greenhouse gas emissions and water use (particularly in agricultural production systems; Kering 2015a). The current framing of the EP&L separates land-use impacts from the other impact pathways (greenhouse gas emissions, other air pollution, solid waste, water pollution, and water consumption; Figure 1), although many of the ecosystem services assessed in the land-use indicator could feed into the other impact pathways (ie equable climate into greenhouse gas emissions, air quality into other air pollution, pollution control into water pollution, and domestic and industrial water into water consumption; Figure 2). Land-use impacts are valued on a per hectare basis, for land occupied or transformed, while the other impact pathways are valued according to the volume of the impact for each pathway (eg kilogrammes of pollutant or cubic metres of water).

It was never assumed that the land-use indicator would capture all impacts on biodiversity but that it would act as a proxy for impacts until it is enhanced to be more accurate. The valuation of land-use impacts rests on three key assumptions (Figure 2). First, that the TEEB database (Van der Ploeg & DeGroot 2010) and related studies provide accurate values of the various services provided by ecosystems in particular places and that these values are transferrable to other, similar settings. Second, that the diminishment of these values are directly proportional to losses in biomass and biodiversity that have been documented globally (IPCC 2006, Ellis et al. 2012). Finally, that representing the functional values of biodiversity (via ecosystem services) is an adequate accounting of impacts to biodiversity more generally.

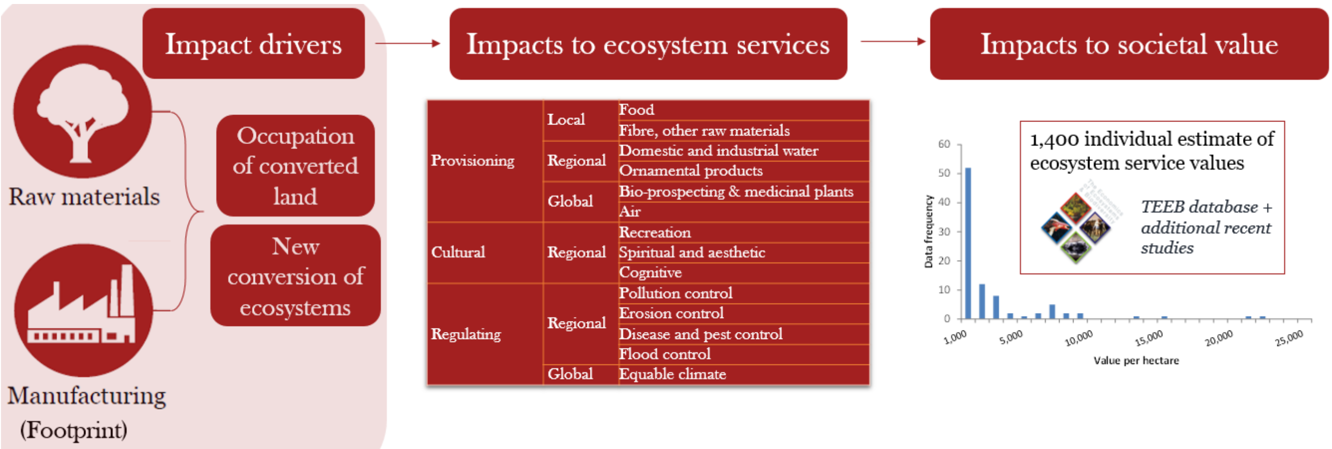

Figure 2: EP&L workflow for the land-use indicator

These assumptions are accompanied by corresponding limitations. First, the databases for both ecosystem value and biomass/diversity losses represent a static view of the world, pinned to the time that the literature comprising the databases was published. They are not updated from year to year to track changes or incorporate new data. Furthermore, such databases abstract the true nature of relationships between biodiversity, ecosystems, services and values, and are unable to represent spatially explicit processes that can lead to very different outcomes depending on the composition and configuration of habitats in a landscape (Chaplin-Kramer et al. 2015; Mitchell et al. 2014). Without accounting for these context-dependent ecosystem processes, it is difficult for the EP&L to assess improvements from a current degraded state in order to represent a company's potential for positive impact, making it a less flexible tool for decision-making than it otherwise could be. Finally, understanding the ecology of a landscape is important not only for ecosystem services and the level of biodiversity needed to maintain them, but also for biodiversity in its own right – and the two may not always be correlated (Strassburg et al. 2012, Naidoo et al. 2008).

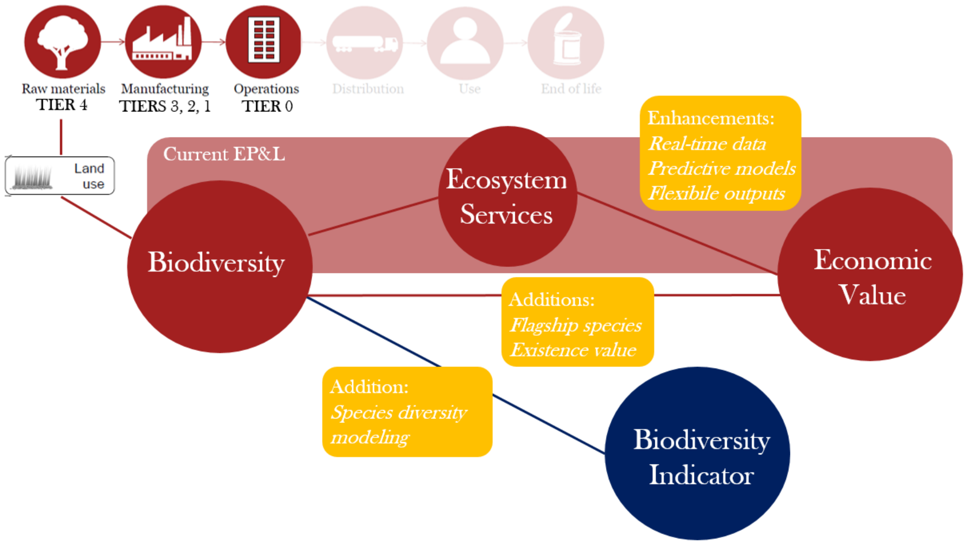

Figure 3: Framework for enhancements to the EP&L for ecosystem services and additions (within the EP&L or as a separate indicator) for biodiversity

There are two critical areas of improvement that can address these limitations, by replacing or enhancing components within the land-use indicator and relaxing the assumptions that constrain the current methodology (Figure 3). The first of these enhancements involves incorporating real-time remotely-sensed data and spatial models, which will not require any change to the data collected or work undertaken by companies. Modifications will all occur "under the hood" in substituting the static database values for those modelled with open-source tools and globally available remotely-sensed data. The second area for improvement addresses aspects of biodiversity that are currently missing in the EP&L, with a recommendation to include an additional indicator for biodiversity that can sit alongside.

2 Ecosystem services

2.1 Enhancing representation of ecosystem services in the EP&L

Ecosystem services are the flow of benefits from nature to people, ranging from provisioning benefits like food and water, to regulating benefits like air and water purification, to a variety of cultural benefits associated with being in nature (Daily et al. 1997). The field of ecosystem services science has advanced dramatically since the Millennium Ecosystem Assessment (MA 2005) introduced the concept to a broader global audience a decade ago. Recent modelling efforts building on detailed empirical work in specific locations have captured more of the complexity of spatial and temporal ecological processes in predicting how ecosystems respond to human activity, and the resulting changes in the provision of ecosystem services to people in coupled human-natural systems (Renard et al. 2015, Mitchell et al. 2015, Ziter et al. 2014, Qiu & Turner 2013). These models are well suited to informing decisions in the particular places for which they were developed, but the local specificity of such models make them impractical to adapt for global use.

Meanwhile, another body of work has assessed ecosystem services on per-area basis, assigning the same value to all habitat of a certain type everywhere it occurred (Costanza et al. 1997). These land-use proxy approaches, sometimes called benefits-transfer, have been mainstreamed in the practitioner community because they can be easily applied anywhere, at a global level. Estimates for ecosystem value have been refined with regionally-specific information, but these methods generally assume a linear relationship between habitat area and the value of ecosystem service provision (Blomqvist et al. 2013, Hellweg & Milà i Canals 2014). This failure to represent important processes governed by spatial context can lead to order-of-magnitude errors in assessment of impact, depending on the assumed configuration of land-use change (Chaplin-Kramer et al. 2015). Approaches that significantly over- or under-estimate the importance of nature to people will ultimately lead to poorer management and a failure of the concept to change the way we manage ecosystems; therefore we see a tension between the practicality of benefits-transfer approaches and the rigor and credibility of more complex, location-specific models of ecosystem services.

Straddling these two approaches, a set of decision tools have emerged in recent years, aimed at bringing real-time information on land use and natural resource management together with the best available science conveying the general principles of ecosystem service provision (Bagstad et al. 2013). Such tools include InVEST (Sharp et al. 2016), WaterWorld (Mulligan 2012), LUCI (Jackson et al. 2013), and ARIES (Villa et al. 2014). InVEST is among the most advanced of these, with a fully open-source code base, active users in more than 80 countries, an average 600 downloads per month, dozens of trainings held around the world each year, and a growing global platform for sharing and serving ecosystem services information.

2.1.1 Introduction to InVEST

The Integrated Valuation of Ecosystem Services and Trade-offs, or InVEST, is a suite of accessible, user-friendly software tools for spatially explicit ecosystem service assessment (Sharp et al. 2016). The current suite includes eighteen ecosystem service models and five helper tools for processing and analysing ecosystem service information, with several more models under development (Appendix A). InVEST uses globally available spatial data derived from satellite or national statistics bureaus on land cover (and related land use or management characteristics), soils, climate, topography, and a variety of socio-economic information. With these inputs, InVEST produces maps and estimates of ecosystem service value under different land-use change (or climate, or other global change) scenarios.

InVEST models represent spatially explicit processes in a land or sea scape and show how changes in ecosystems and their arrangement or management lead to changes in ecosystem services and their values. For example, the value of sediment retention can be expressed in terms of maintenance of soil and its fertility at a particular site, which is a function of the combination of the land management occurring at that site and the erodibility of the soil, steepness of the slope, and erosivity of the climate that together determine its erosion potential. Or, the value of sediment retention can be expressed in terms of the ability of vegetation to intercept soil eroding off the landscape before it reaches the stream and pollutes the water, which is a function of both the erosion potential across the landscape as well as the path that the water takes down a hillside and the vegetation it encounters along the way. This is why the spatial arrangement of ecosystems and where different management occurs relative to other landscape features is so important in understanding the total impact that management will have.

2.1.2 Framework for integrating into the EP&L

The EP&L values a change in land use or management from pristine to current condition, using a benefits-transfer database (TEEB) for the value of a pristine ecosystem, multiplied by the published reduction in biomass (IPCC 2006) and/or vascular plant species richness (Ellis et al. 2012). Similarly, InVEST can value a change in land use or management, by modelling one landscape state and then another, and producing either biophysical or economic values. However, while biophysical inputs are readily and globally available, economic datasets are not as complete in coverage. Therefore as our first point of entry to integrating InVEST in the EP&L, we explore replacing the published reduction in biomass and/or species richness and its assumed linear relationship to ecosystem services with InVEST's more functional representation of the reduction in ecosystem services resulting from a change in land use or management, based on current and globally available remote-sensing data.

2.2 Proof of concept

We take an example of grazing in Mongolia as a proof of concept. Mongolia is an important source of the world's cashmere, and in the fragile ecosystems of the Gobi desert region, there are challenges associated with the conservation of grasslands as well as key endangered species. For this reason, it provides an interesting case study to focus on for the proof of concept. In recent years widespread desertification resulting from overgrazing has threatened the sustainability of cashmere supply from Mongolia. Companies may wish to understand the impacts of overgrazing on a variety of ecosystem services, or to consider the potential for future improvement through better grazing management. Here we show how much of a difference the integration of InVEST can make to the EP&L, by comparing the conventional EP&L's calculation (using estimates of the reduction in biomass and species richness) to the InVEST-modelled reduction in two ecosystem services: erosion control and water pollution control. We apply the InVEST Sediment model with two outputs, soil loss on pixel (for erosion) and sediment export to watercourses (for water pollution). For water pollution, sediment export could be combined with outputs from the InVEST Nutrient model to form a combined index of the two, but in this case we focus on the Sediment model. We have chosen erosion and sediment export for this proof of concept because they are strongly impacted by overgrazing, due to the role of vegetation (or lack thereof, in severely overgrazed conditions) in preventing erosion and retaining sediment (Bilotta et al. 2007).

Different model coefficients were used to represent a livestock management gradient varying from very well managed to very poorly managed, with corresponding effects on the rangeland vegetation and its capacity to provide the pollution control and erosion services and thus corresponding impacts on water pollution and erosion (Figure 4). Details on model inputs and assumptions are included in Appendix B.

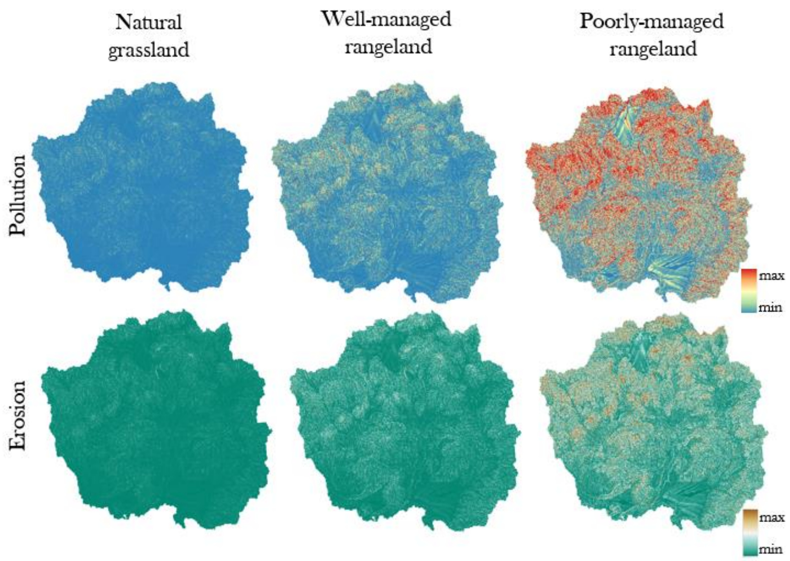

Figure 4: InVEST model outputs for water pollution and erosion

Using the current EP&L methodologies for Mongolia suggests that current conditions have resulted in an 87 per cent reduction in erosion control (assumed from reduction in biomass) and a 92 per cent reduction in water pollution control (assumed from averaging reduction in biomass and diversity) relative to a baseline state (Table 1). InVEST suggests that such a high reduction in biomass in grasslands results in 18 times the soil erosion and 55 times the sediment export to watercourses—meaning there is only 5 per cent of the erosion control service and 2 per cent of the water pollution control service that is available in a pristine grassland (Figure 5). Thus, InVEST estimates 2–5 times greater reductions than the 13 per cent and 8 per cent remaining service calculated by current EP&L methods for erosion control and pollution control, respectively.

	Biomass loss	Diversity loss	Service loss
Erosion control	87%	97%	92%
Pollution control	87%	--	87%

Table 1: Current EP&L assumption for reduction in service for Mongolia

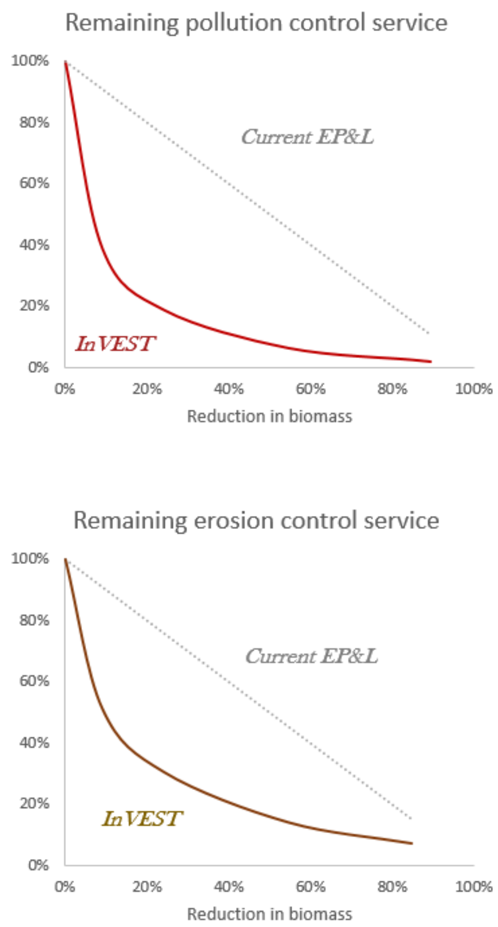

Figure 5: InVEST vs. current EP&L reduction in service

Of course, even a large proportional difference for so small a remaining value will have little impact on the financial contribution to the overall EP&L. However, the proportional difference between the estimates is much greater and will matter much more for slightly more intact ecosystems with a lower assumed reduction in biomass. For example, for a 70 per cent reduction in biomass and species richness, the EP&L would assume that 30 per cent of the pristine level of service for water pollution control is remaining, but the InVEST model suggests only 3 per cent of the service remaining – an order of magnitude difference.

Such differences will become increasingly important as Kering moves toward basing its management decisions upon the results of such analyses to help restore the vegetation and many of the functions of this landscape. The amount of service that can be restored per unit of biomass in a degraded ecosystem depends on where along the curve in Figure 3 the current condition falls. Starting from a level of 30 per cent of pristine condition only restores 0.3 per cent of the water pollution control for every 1 per cent of biomass added, while starting from a level of 75 per cent of pristine condition restores 1.25 per cent of the water pollution control for every 1 per cent of biomass added. Therefore, understanding where on the curve a system currently falls is important to accurately assess the damage caused by additional degradation or the improvement possible through restoration. This is an especially important point for rangeland systems (the source of raw materials essential to many sectors) because their current status is mostly degraded and they have enormous potential for improvement through regenerative grazing.

2.3 Future work to move from proof of concept to becoming operational

We suggest four lines of work to continue to progress from this proof of concept to operationalising these improvements to the representation of ecosystem services in the EP&L.

First, the modelling can and should be expanded to cover broader extents, to better capture the decision relevance of any modelled impacts. This is currently possible through the InVEST data platform, which hosts globally available data for all terrestrial and freshwater ecosystem services models. Both the location and the spatial configuration of the landscape make a significant difference to the magnitude of impacts of a change in land use or management (Chaplin-Kramer et al. 2015), so the better the information of where production occurs on the ground, the more accurate the assessment of ecosystem services impacts for the EP&L. In the absence of this information (eg when companies do not know where their raw materials are sourced from) we suggest developing a methodology for assessing the 'worst case' scenario, identifying the possible sourcing regions in which greatest impacts would occur.

Second, this approach can be extended to more services. There are currently models within InVEST to cover several services in addition to pollution control and erosion control demonstrated in the proof of concept, including other current EP&L ecosystem service categories such as equable climate, water provision, flood control, and recreation (Sharp et al. 2016). Additional models are in development for air quality regulation, food/forage provision (including non-timber forest products), pest control, and cognitive benefits of nature. While certain cultural services may always escape our ability to quantitatively model them, linking the EP&L to ongoing development within the InVEST software suite will allow continual integration of improvements in our understanding and predictive modelling of a variety of ecosystem services.

Third, advances in remote sensing should be explored for their potential to detect current ecosystem state. This would enable a movement away from literature-derived (and therefore likely out-of-date) estimates of biomass reduction toward real-time assessments of biomass or even compositional changes in vegetation, which is important to the accurate assessment of impacts, as noted in the proof of concept. Spectral information remotely sensed from satellites can be processed into indices (eg Normalized Difference Vegetation Index) or used to calculate biomass (Baccini et al. 2012). These metrics could be used directly or combined with producer-level site based estimates to monitor the state of ecosystems on a monthly or even daily basis, to track positive or negative impacts.

Finally, ecosystem service impacts could be valued directly rather than multiplying benefits-transfer values for ecosystems by the expected reduction in services. This could involve two complementary approaches:

- The assembly and maintenance of a database of service-specific replacement or abatement costs, such as water treatment, on a per-impact (eg kilogramme of pollutant) rather than per-area basis, nationally or regionally. Efforts to build such datasets (eg by Earth Economics) could be leveraged to achieve such an aim. These outputs would allow linking the land-use indicator to other impact pathways within the EP&L.
- Improving the representation of beneficiaries in the weighting of values. In the current EP&L the value of ecosystem service impacts is weighted by the proportion of the population in the nation of interest living in rural areas, as a measure of how many people bear the cost of that impact. There are more sophisticated ways of disaggregating the beneficiaries of ecosystem services, including a technique called dasymetric mapping, which interpolates census data to finer resolutions through integration with remote-sensing data (Mantaay et al. 2007). Such techniques produce a more accurate assessment of who is most affected and most vulnerable to disruption in the delivery of ecosystem services.

Overall, advancing the economic analysis to match the complexity of the ecological analysis will be a significant undertaking, but is a critical step for the accuracy and utility of natural capital accounting.

3 Biodiversity

3.1 Biodiversity beyond the current EP&L

Whilst the contribution of biodiversity at the landscape or ecosystem level to provisioning, regulating and cultural services is captured in the current EP&L, there are still measurable impacts on biodiversity that are not reflected in the EP&L accounts and, therefore, go unreported (Kering 2015b; Figure 6). Many of the ecosystem service values that biodiversity provides are either excluded from analyses or the underpinning role of biodiversity is hidden (Bolt et al 2016; Figure 6). For many, the most intuitive unit of measurement for biodiversity, and thus the most often used, is species (Purvis & Hector, 2000). As the EP&L already addresses the effects of landscape or ecosystem diversity on ecosystem services (with improvements described in the previous section), the primary focus for this section is on species diversity.

FIGURE 2: HIDDEN AND MISSING VALUES OF BIODIVERSITY. Figure modified from original in the Natural Capital Protocol

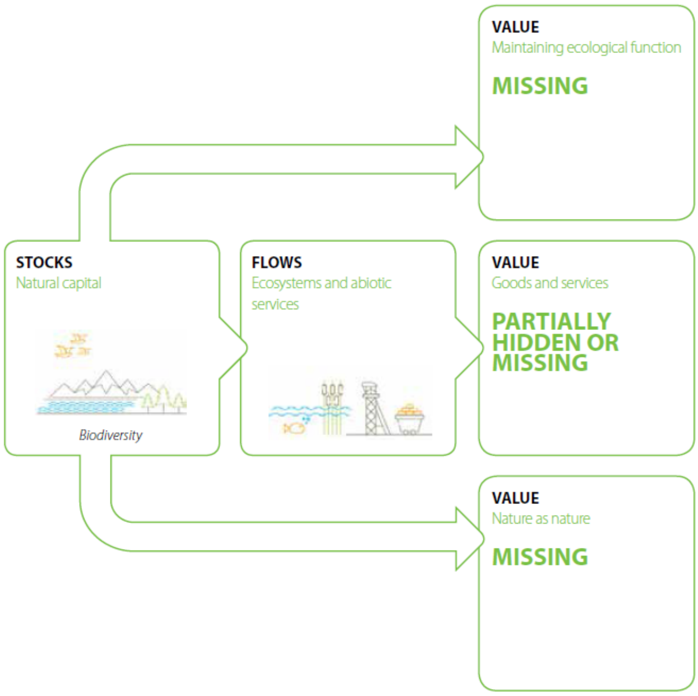

Figure 6, From Bolt et al 2016:

Ultimately, many companies would like to be able to more accurately measure the impacts that their brands have on biodiversity at the raw material production level and evaluate improvements possible through more sustainable sourcing such as switching production systems, harvesting models, or sourcing locations. Natural capital accounting frameworks may not measure impacts on biodiversity at the granularity required, however; for example, the data and methods currently used in the EP&L are not sensitive enough to signal improvements or deteriorations in biodiversity impacts. Some examples in which an improvement in management or sourcing is not currently reflected in an EP&L account may include: impacts on species from particular land use and/or intensity of management; impacts on particular species (eg predators, due to direct harvest or due to impacts on prey via decreasing predation); or impacts on species due to 'wildlife friendly' farming (eg non-lethal predator control).

For the EP&L, the measurement is of impact on human wellbeing, and the monetary value of these impacts can be estimated using principles drawn from the field of environmental economics. These techniques aim to estimate financial values for changes in human wellbeing as a result of changes to the environment (Kering 2015b). The relationship between biodiversity and total economic value can be considered in terms of use value (for either enjoyment of the biodiversity itself or the services it provides) and non-use values, as depicted in Figure 7 (see Appendix C for a table of methodologies).

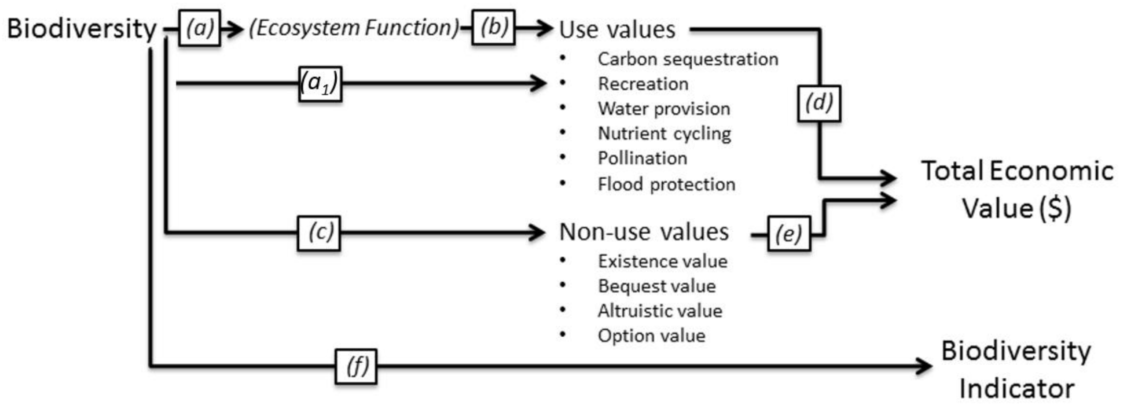

Figure 7: The relationship between biodiversity and total economic value

3.1.1 Difficulties and limitations in the representation of biodiversity in an EP&L

Improving the measurement, valuation and/or reporting of biodiversity at the species level in the EP&L reports is constrained by three key difficulties in incorporating biodiversity into estimates of value.

(1) *Functional roles of species diversity are poorly understood or weak*

Whilst biodiversity in landscapes, ecosystems, species and genomes underpins the provision and resilience of ecosystem function and the services that they deliver, the exact nature of the relationship between biodiversity (especially at the species level) and ecosystem services is not well described for many services (Cardinale et al 2012; Purvis & Hector 2000) (Figure 7 *[a] and [b]*). The direct relationship between biodiversity and cultural values, even without mediation by ecosystem function (Figure 6*[a_1]*), is even less well understood (Satz et al. 2013). Furthermore, it is possible that increasing the abundance or diversity of certain species could boost ecosystem *disservices* (eg greater diversity of pathogens or vectors for disease).

(2) *Calculation of use value remains imperfect*

These imperfections remain despite rapid technical advances in recent years. To translate a reduction of biodiversity and its related ecosystem services into monetary terms, several simplifications, assumptions and caveats must be made (Melathopoulos et al 2015) (Figure 7*[d]*). Problems can be further exacerbated when results from one study are extrapolated to novel situations (benefits-transfer), rather than being calculated for each particular location and situation.

(3) *Calculating non-use values is controversial*

The calculation of non-use values is controversial because surveys cannot be validated against observed behaviour, and techniques can perform particularly poorly when the valuation concerns something that is not well understood, as is often the case for biodiversity (Bateman et al 2014) (Figure 7*[c] and [e]*). Non-use values include existence values (individuals value knowing that a species exists, even when they derive no direct use from it); bequest values (the good feeling derived from preserving biodiversity for future generations); altruistic values (the good feeling derived from maintaining a resource for the use of others); and option value (derived from maintaining a resource for potential use in the future).

In addition to considering biodiversity as the variability among living organisms, a company may wish to pay attention to particular species that are either charismatic for conservation causes or can act as an umbrella for the health and integrity of a particular habitat or ecosystem. Whilst flagship species in themselves are not strictly a measure of biodiversity, they certainly contribute to it, and especially to public perception and experience of it. As an example, a company might take steps to conserve wolves, a flagship species, through implementing non-lethal control by livestock herders who provide wool or leather to their supply chain. However, these actions are not currently represented in the EP&L. The primary values arising from conservation of such species are similar to those for biodiversity as a whole, and thus similar challenges arise in representing them in the EP&L: some flagship species may have a keystone role in their ecosystem, and thus contribute directly to ecosystem functioning and services (Figure 7*[a], [b], [d]*); certain charismatic species such as predators may generate revenues for wildlife tourism (Figure 7*[a_1]*); and existence value is generally high for flagship species, because people tend to know and care about them (Figure 7*[c], [d]*).

3.2 Recommendations for improving the representation of biodiversity

Notwithstanding improvements to the way in which biodiversity and ecosystems are measured and valued via ecosystem services (as described in Section 2), shortcomings will inevitably remain in the ability of the EP&L to fully represent biodiversity. A measure of the impacts upon the biophysical units of biodiversity themselves (eg ecosystems, species, genes) should be reported (

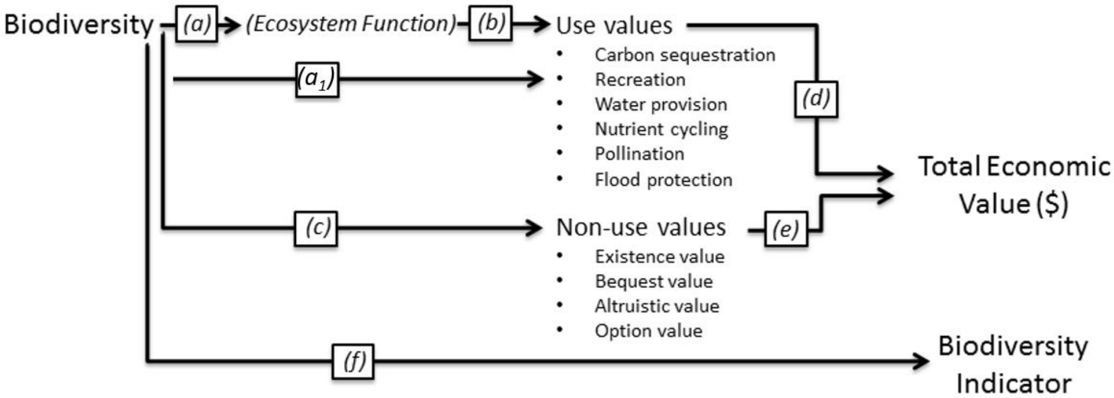

Figure 7*[f]*) in order to:

- Circumvent limitations of current understanding and valuation methods;
- Ensure a 'portfolio' of biodiversity that is resilient (Balvanera et al, 2014);
- Preserve options into the future; and
- Ensure that biodiversity is conserved both for its own sake, and for the benefits that it provides to humans.

3.2.1 Development of a biodiversity indicator

One way of developing an indicator of species diversity that can inform business decisions is through a framework of threats to species posed by the business activities. At a global level, the most important threats to biodiversity are loss and degradations of habitat (together accounting for 45 per cent of species' threat status) and exploitation (37 per cent), with climate change, invasive species and genes, pollution and disease making up the remaining (WWF 2014; Table 2):

Threat	% of total	Example of industry and threat to biodiversity
Loss of natural habitat	14	Farming: conversion of rainforest into pastureland for livestock.
Degradation of habitat	31	Mining: construction of roads through rainforest to access mining sites will increase accessibility, possibly leading to increased harvest of forest products and increased fires, so reducing the quality of the habitat for local species.
Exploitation: direct and indirect effects of wild animal harvest	37	Direct: Fisheries. Overfishing can reduce the ability of fisheries to naturally restock. Indirect: Apparel. Use of wild-harvested reptile skins could lead to a cascade of effects on other species in the ecosystem.
Climate change causing species range shifts	7	Manufacturing: greenhouse gas emissions contribute to rapid global climate change, which may reduce or remove the climatic niche in which a species exists.
Invasive species	5	Apparel: American mink farmed in Europe for fur established in the wild causing significant damage to native biodiversity.
Habitat pollution	4	Manufacturing: pollution of freshwater ecosystems by wastewater.

Table 2: Current threats to biodiversity

Globally, the greatest threats to species arise from loss and degradation of habitat. Within the apparel sector, the relative importance of direct wild species harvest ('exploitation') as a threat to biodiversity is likely to be considerably lower than that depicted in Table 2, which is heavily influenced by fishing and illegal hunting. Climate change and pollution already feature in the EP&L through the modules on Greenhouse Gases and Water Pollution (Kering 2015b). In the apparel sector, invasive non-native species and genes are a threat to animals and plants through, for example, skin and fur farms. However, where procedures have been put in place to assess and mitigate the risks posed and farms are situated in countries with strong environmental regulation around invasive species control, the probability of impact can be reduced (Aiama et al, 2016). Lastly, the contribution of a single business to the spread of disease or susceptibility of wild species populations is difficult to assess, but is expected to be a relatively small proportion of the impact of business operations on biodiversity. The focus of the remainder of this section will therefore be on habitat degradation and loss because it is the primary mechanism through which biodiversity is being lost, and because this threat also has the most rigorous data and methods available for a global analysis of impacts. There is a wealth of indicators and assessment tools available, although none is perfect. An exploration of promising data and metrics to include in a biodiversity performance indicator can be found in Appendix C.

There are some pragmatic concerns in developing a metric. First and foremost, the metric should be as honest as possible, both in reflecting genuine changes in biodiversity and in providing a transparent and trusted framework by which the changes are assessed. Data must be available globally, in order that the metric can be applied to all supply chains. However, data for a particular farm or production system should be substituted for average global impacts when available.

3.2.2 Habitat degradation and loss: impacts on local biodiversity

In the following sections, we review one potential approach and dataset for developing a species diversity indicator metric. Alternative approaches for assessing species impacts of habitat change are presented in Appendix C, alongside options for including other business impacts.

The Projecting Responses of Ecological Diversity in Changing Terrestrial Systems (PREDICTS) project has established a database with over three million records for over 50,000 species (Hudson et al, 2014). The data are from scientific records and, with many species groups well covered, comprise one of the most representative species diversity databases in the world. The data are being used to quantify how different land uses and management intensities impact species (Newbold et al, 2015). The team have also developed a Local Biodiversity Intactness Index (LBII; Purvis, 2016; Scholes & Biggs, 2005), a flexible indicator that provides transparent and credible estimates of the 'intactness' of species diversity that could be used for a range of decision contexts (Scholes & Biggs, 2005). The LBII estimates how much of a site's biodiversity remains compared to its original land cover, although in theory other baselines could be considered. The index can be measured at local scales (1km resolution) or aggregated to sub-national, national or regional estimates and, importantly, data can be selected from ecologically meaningful units (eg ecoregions), rather than just administrative boundaries (eg countries) that are often used to record and report data.

The LBII can be based on species richness or mean species abundance or, currently in development, species geographic range rarity or phylogenetic diversity. The LBII could be reported as a rate of change over the reporting period (based on modelled impacts of the effects of land use) or simply the intactness (expressed as a per cent) of biodiversity compared to the original/baseline habitat. The PREDICTS data have been used to assess scenarios of land-use change (Newbold et al, 2015) and could, in theory, be used to explore alternative sourcing scenarios in supply chains.

Box 1: Example – Habitat degradation and loss from grazing

The impact on biodiversity is assessed in terms of reduced 'biodiversity intactness' (Purvis 2016) when natural habitat is converted to livestock pasture:

1. Define the source location. This may only be known to the country level, but the better the resolution, the more precise the results can be.
2. Species that are associated with the baseline (natural) habitat within the defined area are estimated from the PREDICTS database (see Hudson et al 2014).
3. Species associated with converted habitat (livestock pasture) within the defined area are estimated for three measures of farming intensity: low, medium or high.
4. An intactness score (see Purvis 2016) is calculated for both, reflecting how conversion from one habitat to another is expected to impact species.
5. The impact attributable to a company is estimated using the change in intactness and information on total production area.

3.2.3 Biodiversity in decision-making

In order to give some context to a biodiversity indicator, decision-makers may wish to consider an estimate of the cost to reinstate the biodiversity that has been lost. This could incorporate information on the cost of purchasing and restoring 'equivalent' parcels of land in order to preserve species that are expected to be lost from production landscapes. A similar cost of averting losses might also be calculated for other threats, such as greenhouse gas emissions, pollution and wild species harvest. Whilst such an approach does not represent the value of biodiversity, and thus should not be included in the EP&L directly, it may serve as a useful way to think about the cost of averting species impacts. It will allow a comparison of the costs of mitigating biodiversity losses to those incurred by a particular decision with respect to lost profits (a regular P&L) or the foregone social benefits (an EP&L). This approach may be most relevant to high-impact operations such as those found in extractives industries, but could be extended to raw material production to the extent that it is not possible to reduce threats to certain species or ecosystems even through sustainable production (eg forest-obligate bird species in row-crop or shade-intolerant agricultural production).

The Biodiversity Consultancy has developed methods and a related database for evaluating a range of restoration costs across the world's biomes (TBC 2015). Expanding this database to track costs in different countries or regions as well as biomes, and developing a similar database on land-purchasing price would be necessary to operationalise this for broader use. Furthermore, restoration hectare for hectare rarely restores the same level of biodiversity that was lost from habitat conversion or degradation, and thus the idea of mitigation ratios have been established to ensure that enough habitat is restored to support species at the same level. A database on mitigation ratios for different biomes or ecosystem types would also be needed. However, this method would be fairly straightforward to apply if decision-makers found it useful.

If a biodiversity indicator is developed, but a company finds it impractical to use as a reporting tool, then an alternative is to set up a constraint. The indicator can be used to constrain the space within which the company operates in the same way that companies regularly commit to eliminating certain practices or impacts from their supply chains. The boundaries for biodiversity impact within which the company operates could be set a priori – for example no net loss. This approach was taken for the recent National Ecosystem Assessment for the UK, allowing biodiversity to be represented in an ecosystem service assessment without attaching to it a monetary value (Bateman et al, 2014).

4 Further recommendations from meeting of experts

On June 2–3, 2016, a panel of experts and stakeholders was convened by Kering and CISL to evaluate these approaches and make recommendations for next steps. The experts were split into two groups to focus separately on the ecosystem services enhancements to the EP&L and the proposed biodiversity indicator. Within each group, the experts first agreed on the principles that are important for any approaches to be adopted for improving the integration of biodiversity and ecosystem services in natural capital accounting and business decisions. Then, depending on the group, pilots were discussed (for ecosystem services) or the framework for an indicator was further refined (for biodiversity). These ideas were tested with business stakeholders to identify particular questions and problems that could be addressed, and where gaps remain.

4.1 Expert recommendations for ecosystems services

For ecosystem services, the principles that experts agreed should guide the approach included: 1) systems-focused, with adequate representation of spatially and temporally explicit processes for the ecological as well as economic modelling; 2) sensitive to management, and able to reflect changes resulting from the types of changes business could promote, with representation of uncertainty; 3) nested in complexity to allow different levels of detail for different types of decisions; and 4) practical and scalable, using globally available data at least at the lowest tier of complexity, with the ability to substitute better information where available to answer more refined questions.

There were additional concerns voiced, especially on including indices of ecosystem health rather than simple categorisations of 'land use' to address the systems-focus of the first agreed principle, and allowing for collection of economic data needed to run site-specific economic models for higher tiers of complexity in the third principle. There was also some discussion about valuing key species (keystone/indicator species for regulating or provisioning services or flagship/charismatic species for cultural services); it was agreed that this would require further scoping to determine the feasibility for inclusion within the EP&L.

Possible pilots identified by the ecosystem services group included: agroforestry systems, cotton, and grazing systems like that shown in the proof of concept. Experts considered that a diversity of contexts would better illustrate the power of the proposed approach. Agroforestry, such as viscose supply chains (for which Stella McCartney is currently conducting an LCA on the global supply chain focusing on degraded systems as a point of comparison) or rubber, provide an example that many experts considered having a higher potential to return the system closer to the natural state. Cotton provides the counter-example, with a much higher contrast between the natural and managed states, but with perhaps still significant room for improvement through management. Consensus emerged around the idea of taking a multi-staged approach, following the principle of nested complexity (principle 3 above), starting with screening for the greatest potential for improvement through management in a region or landscape and then following up with a site-assessment for quantifying and valuing how much difference those management changes could make. The screening process would rely on globally available data, including remote sensing and national datasets, while the site assessment would also integrate direct site measurements.

4.2 Expert recommendations for biodiversity

For the biodiversity indicator, the experts agreed this could be used to inform a number of business areas, including: strategic sourcing, risk mitigation, ethical considerations, finance, partnerships, capital investments, portfolio management, credit access, regulatory or voluntary compliance, resilience to future shocks and additional credibility to complement other commitments.

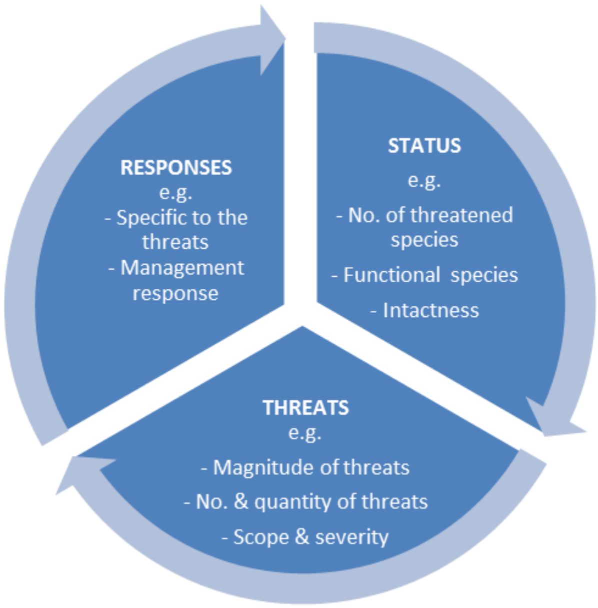

Figure 8: Possible conceptual framework for a biodiversity indicator that captures key elements to evaluate impact

Threat to biodiversity, status of biodiversity stocks and regenerative capacity of the system were suggested as potential lenses through which to assess how biodiversity is impacted and therefore to capture overall risk.

There was enthusiasm for a simplified index to represent the impact on biodiversity which would have to be based on rigorous and complex data. There was discussion that this indicator could serve to demonstrate a) the current status of biodiversity; b) the drivers and mechanisms that threaten future biodiversity in the future; and c) management actions that are a response designed to mitigate or reverse threats. In this way different timescales can be incorporated and businesses can use the analysis to make informed decisions (Figure 8).

Whilst measuring the status of biodiversity may give the 'truest' metric of impact on biodiversity, it will inevitably not allow a business to be as responsive as if a metric of management or threats is used. These allow the metric to pick up on the *intent* of a management action. It was recommended that rather than one indicator, several indices could be used to represent impacts on biodiversity (see Appendix C) and these could potentially be aggregated into one score without loss of information on the contribution of each index. An illustrative example is shown in Figure 9.

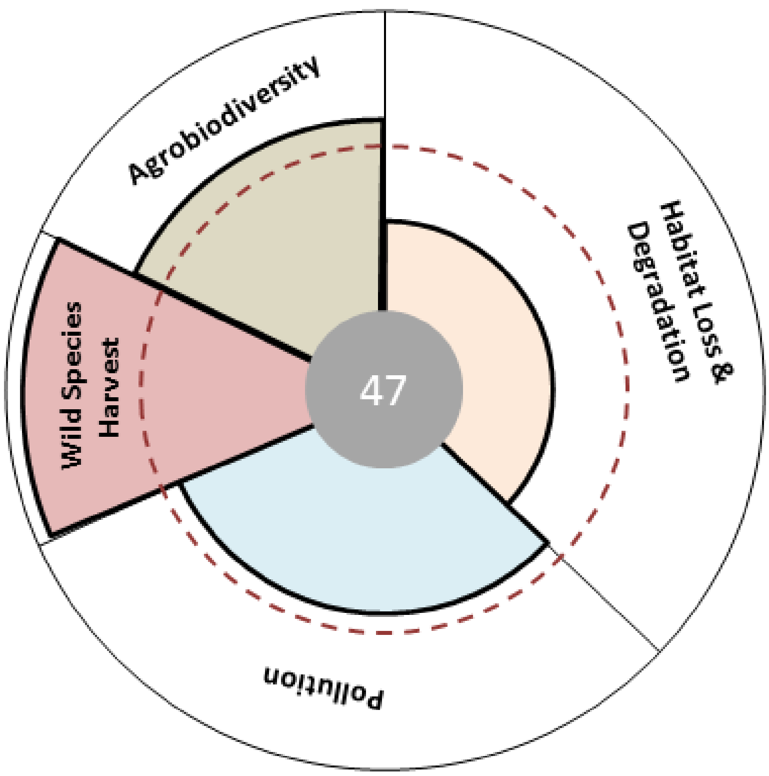

Figure 9: Illustrative visual of a biodiversity index

5 Conclusions

1. Real-time remote-sensing information can be combined with spatially explicit ecosystem services models to better represent impacts to biodiversity at the ecosystem level and related ecosystem services in the EP&L. Initial findings suggest this will transform our understanding of impacts, but will not require any change to the use or preparation of the EP&L methodology.
2. According to the precautionary principle and due to our lack of understanding and valuation methods for assessing the full value of biodiversity, businesses should develop a metric to assess its biodiversity impacts that is independent of the human welfare benefits that we are currently able to assess and incorporate into an EP&L framework. This could be trialled initially for the impacts of land use on species-level diversity, as this is both where the impacts are expected to be largest and where the best data exist for such an assessment.
3. The benefits of specific biodiversity-friendly practices (eg wildlife-friendly) are currently not reflected in the EP&L. The existence value provided by the presence of flagship species could be assessed through a review of existence values for individual species and compiled into a database for use in the EP&L.
4. Operationalising these recommendations will be facilitated by linking to data and modelling platforms for biodiversity and ecosystem services such as PREDICTS, InVEST, and others that can be explored through a second phase of work.

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7 Appendix A: InVEST Models and Tools

InVEST is a suite of free, open-source software models used to map and value the goods and services from nature that sustain and fulfil human life. The multiservice, modular design of InVEST provides a tool for balancing the environmental and economic goals of these diverse entities. InVEST enables decision-makers to assess quantified trade-offs associated with alternative management choices and to identify areas where investment in natural capital can enhance human development and conservation. The toolset currently includes 18 distinct ecosystem service models designed for terrestrial, freshwater, marine, and coastal ecosystems, as well as a number of 'helper tools' to assist with locating and processing input data and with understanding and visualising outputs.

7.1 Ecosystem Service Models

InVEST models are spatially explicit, using maps as information sources and producing maps as outputs. InVEST returns results in either biophysical terms (eg tonnes of carbon sequestered) or economic terms (eg net present value of that sequestered carbon). The spatial resolution of analyses is also flexible, allowing users to address questions at local, regional, or global scales.

InVEST models are based on production functions that define how changes in an ecosystem's structure and function are likely to affect the flows and values of ecosystem services across a landscape or a seascape. The models account for both service supply (eg living habitats as buffers for storm waves) and the location and activities of people who benefit from services (eg location of people and infrastructure potentially affected by coastal storms).

InVEST models can be run independently, or as script tools in the ArcGIS ArcToolBox environment. Running InVEST effectively does not require knowledge of Python programming, but it does require basic to intermediate skills in GIS software. The tool is modular in the sense that you do not have to model all the ecosystem services listed, but rather can select only those of interest.

The currently available ecosystem services models include:

Carbon Storage and Sequestration
Coastal Blue Carbon
Coastal Vulnerability
Crop Pollination
Fisheries
Habitat Quality
Habitat Risk Assessment
Managed Timber Production
Marine Fish Aquaculture
Marine Water Quality
Nearshore Waves and Erosion
Offshore Wind Energy
Recreation
Reservoir Hydropower Production (Water Yield)
Scenic Quality
Sediment Retention
Water Purification
Wave Energy

InVEST also includes the following Helper Tools:

Scenario Generator – offers a relatively simple method of generating scenarios based on user-defined principles of where land changes could occur and the possible extent of these changes. It can be used to create alternate futures, the likely outcomes of which can be compared using InVEST.

Overlap Analysis – estimates the relative importance of regions for human use. Outputs can help decision-makers weigh potential conflicts among spatially explicit management options that involve new activities or new infrastructure. The output maps help visualise hotspots of land or ocean use, and areas where the compatibility of various activities should be investigated when drafting new zoning or permitting schemes.

DelineateIT – delineates watersheds for points of interest along a stream network (eg drinking water intake points, hydropower facilities, reservoirs). Using a DEM, DelineateIT identifies the area upstream of points of interest and creates watershed maps for use as inputs to InVEST freshwater models or for other analyses.

RouteDEM – calculates flow direction, flow accumulation, slope and stream networks from a DEM using the d-infinity flow direction algorithm. RouteDEM outperforms routing algorithms as implemented in other free and proprietary GIS software.

InVEST can be downloaded at http://www.naturalcapitalproject.org/invest/

8 Appendix B: InVEST inputs and assumptions for proof of concept

Methods used for the proof of concept in Mongolia

The following methods were used to compare outputs from the InVEST Sediment Delivery Ratio (SDR) model to traditional EP&L assumptions for service reduction. InVEST was run with potential natural vegetation (PNV) and current LULC to determine the per cent reduction in ecosystem services from baseline. This per cent reduction was then compared to the per cent reduction in the EP&L database for biomass and species richness, which are applied linearly to ecosystem values per hectare.

1. Gather inputs for Mongolia (from InVEST global data set):
    a. DEM (panels)
    b. Erosivity layer (global)
    c. Erodibility layer (global)
    d. LULC (panels)
        i. MODIS (panels)
        ii. Potential Natural Vegetation (download)
    e. Hydroshed (select the one(s) overlapping Gobi)
    f. Biophysical parameter table (see Grazing Effects on soil erosion and transport, below)
    g. Other parameter values – Threshold flow accumulation, kb, IC0, SDRmax (used default values)
2. Clip all inputs to Hydroshed that fully encompasses the Gobi desert region
3. Run SDR for three scenarios:
    a. PNV (all natural grassland)
    b. MODIS with InVEST parameter values for bad grazing management
    c. MODIS with InVEST parameter values for good grazing management
4. Collect the following outputs from the MODIS and PNV runs:
    a. usle_tot: total amount of potential soil loss (soil degradation)
    b. sed_export: total amount of soil exported to stream (water quality)
    c. usle.tif: map of usle
    d. sed_export.tif: map of export

Detailed information on SDR model inputs

Input	Type	Source	Pre-processing
DEM	Raster 90m	SRTM	None
Erosivity layer	Raster ESRI Grid 30 arc-secs (~1	Calculated from monthly precipitation (WorldClim) based on empirical relationship developed by Vrieling et al.	• Clipped monthly datasets (12 total) to Volta • Reprojected from GCS

	km)	(2010)	(lat/long) to World Mercator (m) • Erosivity calculated using the modified Fournier Index (Eq. 5 in Vrieling et al.)
Erodibility layer	Raster 1km	Calculated from ISRIC data, now available on InVEST global database	
LULC	Raster 500m	MODIS	
Watersheds	Vector	Raster provided by Mark	• Converted catchment raster to vector • Reprojected from GCS (lat/long) to World Mercator (m) • Dissolved into one polygon • Created "ws_id" field
Threshold flow accumulation	Integer		• Re-projected from GCS (lat/long) to World Mercator (m) • Sinks removed due to resampling during reprojection
Biophysical table including, per LULC: • USLE C factor* • USLE P factor*	Decimal Decimal	Biophysical table included in InVEST parameter database and additional literature review	See "Grazing effects on soil erosion and sediment transport" summary below

Grazing effects on soil erosion and sediment transport

Empirical evidence

The effect of grazing on soil erosion varies broadly, in particular with soil type, soil wetness, and animal type (Trimble and Mendel, 1995; Warren et al., 1986). The main processes involved with grazing are the reduction of vegetation cover and breaking down of soil aggregates (NRCS-USDA, 2003). A good review is provided by Bilotta et al. (2007), detailing the processes and factors influencing the response to grazing of soil and vegetation properties.

Empirical studies consistently show an increase in soil loss with grazing intensity, often with a non-linear effect (Dunne et al., 2011; Mwendera and Saleem, 1997; Trimble and Mendel, 1995; Warren et al., 1986); although Wine (2012) did not observe any effect on soil loss. Bilotta et al. (2007)

provide a review of the evidence of the effect on soil properties, vegetation, and water quality, showing a great variability in response due to environmental factors (soil type and vegetation).

Modelling

The variability in sediment response prevents the development of quantitative, deterministic representations of the soil processes (Bilotta et al., 2007). One common approach to estimate soil loss is the USLE (Wischmeier and Smith, 1978), which is based on empirical factors related to soil, vegetation, and climate. The approach can be used to represent the effect of a loss in vegetation cover, by referring to look-up table linking the C factor to vegetation cover (note that this neglects the effect of grazing on soil erodibility due to the breaking down of soil aggregates).

Case study in Mongolia

A few studies have examined the effect of grazing on soil erosion in the Mongolian desert. A study of five sites with increasing grazing intensity in Inner Mongolia, Kolbl et al. (2011) demonstrate the effect of grazing on soil properties, in particular on topsoil texture, which directly affects soil erodibility. The empirical data from Muller et al. (2014) also show that grazing intensity affect soil properties as well as biomass, with a quasi-linear relationship; in their study, they found a decrease in biomass of ~55 per cent between the lowest and highest intensity of grazing.

Zhao et al. (2005) collected empirical data on the vegetation cover in grazed and ungrazed pastures and found ~80 per cent cover on grazed sites, vs. 25 per cent on heavily grazed sites. Karnieli et al. (2013) confirm the effect of grazing, although their estimate of current vegetation cover for ungrazed sites is lower (66 per cent, vs. 52 per cent for grazed pastures). Based on the estimates of percentage vegetation cover, Priess et al. (2015) derive C factors for currently grazed pasture based on the tables proposed by Wischmeier and Smith (1978).

In our analyses, we use the approach proposed by Priess et al. to derive the C factor of ungrazed pasture (66 per cent cover based on Karnieli et al.) and then various levels of degradation (corresponding to approximately 25 per cent, 50 per cent %, and 85 per cent loss in biomass). We note that this approach neglects the effect of grazing on soil erodibility, likely underestimating soil erosion from grazed pasture.

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9 Appendix C: Data and opportunities to extend the biodiversity indicator

9.1 Adding further metrics to a biodiversity indicator

While our initial focus for the biodiversity indicator has been on habitat loss and degradation, the indicator could eventually incorporate other metrics, such as pollution, loss of agrobiodiversity or unsustainable wild species harvest. Figure 9 in the main text shows how different information might be combined to provide an overall biodiversity indicator score without losing vital information held within each metric. It represents an example of aggregation of metrics to form a single biodiversity indicator. Segment sizes can be adjusted to weight each metric according to its importance or quality (as above), or segments can be equal. A marker (dashed line) can be set to indicate a critical threshold, target or baseline. Note that the figure is for illustrative purposes only and does not reflect any information held on actual impacts. This kind of aggregation is used, for example, in the Ocean Health Index, where each segment equally contributes to the overall score (Halpern et al, 2015). The indicator is flexible, allowing a supply chain perspective by applying it to a particular commodity; an industry perspective by applying it to a brand or company; or a consumer perspective by applying it to a particular product.

To generate a single indicator score, scores from each metric will have to be normalised to a unit-free index (eg 0–100) and integrated. The normalised components can be weighted according to particular attributes, including:

1. The quality of the data that underlie each component (as in the Environmental Performance Index; Hsu et al, 2016);
2. An expert assessment of the expected importance of each component in measuring threats to biodiversity. For example, a habitat degradation metric could be given greater weighting than a metric that assesses threats to biodiversity from disease (as shown in Figure 3 in the main report)
3. The relative ability of the component metrics to reflect actual impacts on biodiversity.
4. A quantification of the effects of each component indicator on species. Similar to monetisation in an EP&L, the conversion of each metric into a common currency can allow for the proportional representation of that metric in the indicator. This might be a measure of impact on species, such as effects on mean species abundance or likelihood of local extinction, or it might be the cost of mitigating the damage (note that this is different to the *value* that biodiversity provides: see biodiversity in decision-making, below);
5. Component metrics can be given equal weights. This avoids subjective assessment of the relative weighting of components and is used in the Human Development Index and the Ocean Health Index (Halpern et al, 2015). However, it is only justified if each component is of similar importance for biodiversity.

Below we provide a brief description of additional data and opportunities for developing additional metrics for the other globally important threats facing biodiversity that could be included in this summary indicator.

9.2 Exploitation

Some of the species used in the apparel sector are potentially threatened by overexploitation. A measure of the degree to which a company contributes to the decline of utilised species is useful and could be incorporated into the metric.

First, all species utilised within the supply chain should be cross-checked against the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to check whether they are listed on any of the appendices. The IUCN RedList (IUCN, 2015) of threatened species should also be checked (both national and international) to see whether hunting, trapping and direct utilisation of the species are contributing to population declines.

Second, for species appearing on these lists, the management system of the source population should be assessed. For wild harvested species, the worst-case scenario is that a company has no information on the impact of its sourcing on the population of the species. Where the source is known, a series of questions should be asked to establish, amongst other things, whether a sustainable harvest management plan is in place; whether the source population is decreasing, stable or increasing; and whether the best-practice guidelines for sustainable harvest are being followed (see Aiama et al (2016) for more information). For farmed species, the impact on local habitat should be assessed (eg are local habitats degraded by pollution from farms) and the risk of non-native farmed species escaping and causing local native biodiversity declines should also be considered (Aiama et al, 2016).

With the help of experts, the status (CITES and RedList) and management of source populations can be used to derive a scoring system that accounts for both negative and positive impacts on species threatened by overexploitation.

1.1.1.1 Example: Exploitation of precious skins

The apparel sector uses skins from Nile Crocodiles; a species that is CITES listed, but not currently threatened with extinction according to the RedList. An assessment is then needed (after Aiama et al, 2016) to identify where the crocodiles are sourced from and, among other factors, whether the source populations:

1. Have credible sustainable levels of harvest been established?
2. Are harvested using currently established best management practice (eg harvesting during particular seasons or during particular life stages)?
3. Have sustainable use plans implemented for them?
4. Are stable or increasing

The information collected should be scored according to expert opinion on the best way to manage any particular species. Scores should be averaged across all non-domesticated species

It is important to highlight that there may be indirect effects of utilisation, such that whilst a particular population that is harvested to feed a supply chain is increasing, legal and sustainable trade may be facilitating illegal or unsustainable trade either through generating wider demand for the product (causing increased harvest elsewhere) or by allowing unsustainably harvested wild populations to be traded through certified facilities (Aiama et al, 2016).

9.3 Climate change

There are few data with which to assess, globally, the impact of climate change on biodiversity. However, climate change is expected to combine with other threats to biodiversity (Aiama et al, 2006; WWF, 2015) and businesses should therefore aim to minimise greenhouse gas emissions in its supply chains. Data used in existing EP&L frameworks to estimate greenhouse gas emissions costs can be repurposed within the biodiversity metric to include a measure of performance with regard to this specific threat. The metric could be considered in terms of tonnes of carbon dioxide equivalents (tCO_2e). Alternatively, if there was a need to scale this metric to the other metrics to be used in the biodiversity indicator, it might be possible to devise a way in which the estimated effect of CO_2e could be related directly to impacts of species. Whilst this would necessarily be extremely approximate, the GLOBIO methodology, in which Kering's net CO_2e emissions could be calculated as a proportion of the expected global mean temperature increase, could be regressed against mean species abundance (as in Alkemade et al, 2009). Whilst this is crude, it could be explored further to give an approximate weighting for this metric if one were needed (see EEA, 2009; Leadley et al, 2013).

9.4 Pollution

In manufacturing and extractive industries particularly, agrochemicals and wastewater can be a significant environmental pollutant, resulting in direct toxic effects to aquatic and terrestrial wildlife as well as eutrophication (Aiama et al 2016). Several methods have been proposed to monitor and address application of excess nutrients (particularly phosphorous and nitrogen) in farming systems (eg SISC). Methods already exist to capture the cost of water pollution through measurement of toxic pollutants as well as nutrient pollution (Kering 2015b). Quantitatively relating pollution to effects on species or biodiversity is difficult to generalise, but in general, attempts to reduce water pollution should also positively impact local biodiversity. Opportunities exist to improve this by integrating spatial information on pollution with spatial information on biodiversity in order to enable a more specific measure of biodiversity impact.

9.5 Practice-based metrics

The way in which land is managed can have significant effects on the biodiversity impact of farming or livestock management. Therefore, actions taken specifically to benefit biodiversity could be considered for inclusion as a separate metric within the indicator (Tittensor et al 2014; EBBC, 2013; SISC, 2015). Such techniques are regularly used and, for example, could include the area (expressed as a proportion) under specific types of management or certification (eg organic agriculture; conservation agriculture; 'wildlife friendly' farming; rainforest alliance certification) as a proxy for reduced impacts on biodiversity.

9.6 Agrobiodiversity

Whilst the threats to wild plants and species (as shown in Figure 3 in the main report) in the main report) are not pertinent to impacts on the genetic diversity of domesticated plants and animals, agrobiodiversity should not be ignored. Several studies have described the decreasing genetic diversity found in modern farming systems and highlighted the importance of using native breeds and locally adapted seed varieties to maintain reservoirs of genetic diversity, and increase resilience of crop and livestock yields under local conditions (Hoffman, 2013). Several studies into indicators for biodiversity impacts suggest the inclusion of the measures such as the percentage of production sourced from at-risk domestic breeds or the share of production arising from locally adapted breeds and varieties (EEA, 2003; EEA, 2009; Tittensor et al, 2014).

9.7 Invasive non-native species and genes

Invasive non-native species and genes are a threat to animals and plants. The apparel industry is primarily implicated through its use of farmed animal species in non-native areas. An example is fur sourced from American mink farms in Europe. However, where such farms are situated in countries with strong environmental regulation around invasive species control and procedures have been put in place to assess and mitigate the risks posed, the probability of impact can be reduced (Aiama et al, 2016). This threat is not dealt with in this report other than to highlight that certain species pose a particularly potent risk to indigenous plant and wildlife (see Aiama et al (2016) GISD for more information).

9.8 Disease

The contribution of a particular business to the spread of a disease or the susceptibility of wild species populations is not assessed here and is not expected to be a significant impact of business operations.

Type	Methods	Example values
Provisioning	- Price-based direct market valuation - Production function	Wild harvest
		Option value
Regulating	- Avoided cost - Replacement cost - Mitigation/restoration cost - Production function	Pest control
		Pollination
		Water regulation and purification
		Soil fertility
Cultural	- Revealed pref. - travel cost method - Revealed pref. - hedonic pricing	Recreation/tourism
		Spiritual/aesthetic
		Education
		Mental wellbeing
Non-use	- Contingent valuation (WTP/WTA) - Choice experiments - Group valuation	Existence
		Bequest
		Altruistic

Table S1: The total economic value of ecosystem services includes market values (ie for elements that pass through formal markets, such as timber), and non-use values. It does not, however, include any measure of biodiversity's non-utilitarian value.

Table S1. A list of potential datasets for use in estimating biodiversity impacts. This list is not comprehensive but gives a flavour of some of the more promising types of data available.

Measures	Data	Description	Reference
Habitat	PREDICTS & Local Biodiversity Intactness Index (LBII)	An index based on land use data (updated annually and at 1k res) and a new, representative database of species records (>3.3m records, >50k spp)	PREDICTS; LBII
Habitat	Biodiversity Habitat Index (BHI)	Complements LBII (above) with wider landscape perspective on habitat condition. Bases assessment on species data and gamma diversity.	BHI
Habitat	GLOBIO	Based on cause-effect relationships derived from the literature, GLOBIO is a modelling framework to calculate the impact of environmental drivers on biodiversity (terrestrial and freshwater) for past, present and future.	GLOBIO
Habitat	Global Forest Watch	Includes maps of forest loss from 2001–14. Also uses near real-time tree-cover loss (ForMA – forest monitoring for action): to identify 500m pixels in humid tropical forests where loss is likely to have occurred.	
Habitat	Area under wildlife friendly management (%)	Use to identify areas that are specifically managed to benefit wild species, such as organic agriculture, 'wildlife friendly' farming, and sustainable certification schemes. More relevant in areas of high nature value farmland.	EBBC, 2013; Tittensor et al, 2014
Exploitation	Wild Commodities Index	Track changes in population size, sustainability of use and price of wild-harvested species	BIP; Tittensor et al, 2014
Exploitation	RedList species	List of species threatened by over-exploitation	Tittensor et al, 2014
Exploitation	CITES species	List of 36k animal and plant species protected by CITES against over-exploitation through international trade	UNEP, 2014; Tittensor et al, 2014
Agrobiodiversity	Livestock/crop genetic diversity	Identify percentage of livestock in supply chains as 'breeds at risk' and/or the share of production that is from locally adapted breeds/varieties. There is no agreement among countries on the definition of 'locally adapted' breeds and this kind of metric is rarely recognised in these kinds of assessments. It also has links to native wild biodiversity and cultural heritage.	EEA, 2003; EEA, 2009; Tittensor et al, 2014
Pollution	Herbicide/Pesticide use	Agrochemical use per unit of production can be used as a proxy for pollution from (eg) fertilisers, herbicides and pesticides.	UNEP, 2014; Tittensor et al, 2014
Pollution	Nitrogen Balance	An important contributor to water pollution, but data can be patchy, often at national scales and infrequently updated.	EEA, 2003; EEA, 2009; IPNI
Aggregate	Local Ecological Footprinting Tool (LEFT)	For mapping/identifying ecological important landscapes based on habitat; (threatened) species; connectivity; vulnerability. However, does not compare to baseline and cannot be used to assess effect of change in habitat.	
Habitat	Map of Life	>300m species, but not for commercial use.	