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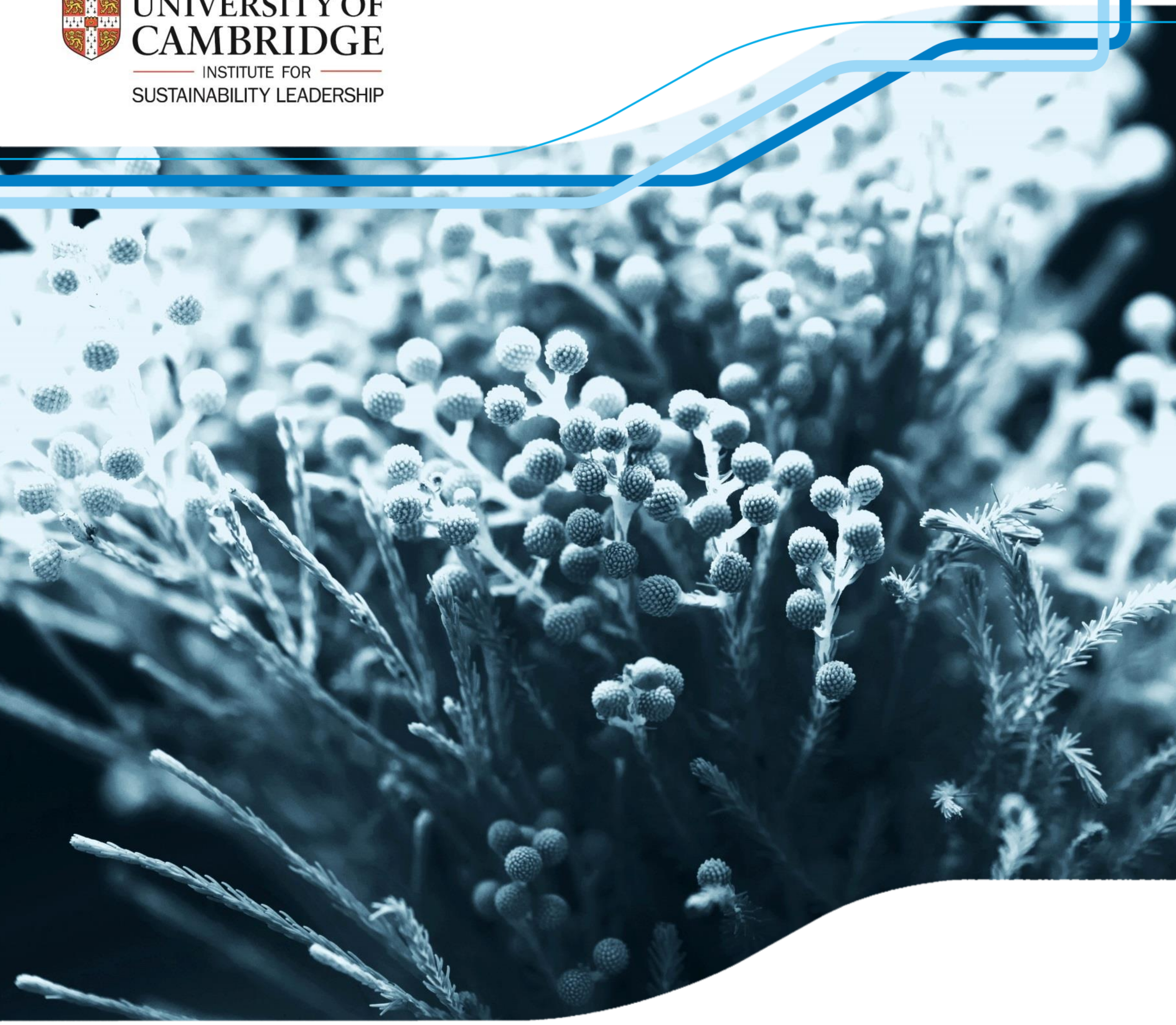

Healthy ecosystem metric framework: biodiversity impact

A working paper by the University of Cambridge Institute for Sustainability Leadership

The University of Cambridge Institute for Sustainability Leadership

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Authors

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Executive summary

Investors and companies alike want to create long-term value by mitigating risks and improving their impact on the natural environment. Company productivity is dependent upon a resilient environment and reducing impacts is beneficial to both nature and business. Opportunities exist for investors and companies to demonstrate positive impacts and show they are reversing the trend of natural environment degradation. The challenge is to identify metrics that are relevant for businesses' decision-making processes, whilst being simple and practical for investors to use.

To date, different initiatives have developed a series of metrics related to natural capital. The uptake of measures and approaches to natural capital is growing within corporate contexts, especially with the release of the Natural Capital Protocol and with leaders such as Kering who have shared their Environmental Profit and Loss (EP&L) methodology.

A need has been identified for a single impact metric which is simple and influential to decision-making across corporates and investors. This working paper is the first step towards a proof of concept for such a metric; it builds upon existing approaches and guidance with the aim of providing consistent, context based metrics that can support corporate decision-making and demonstrate positive impacts. The next step is to test it with companies and investors in real business contexts.

Members of the Natural Capital Impact Group and Investment Leaders Group came together with other experts in academia, corporate sustainability and biodiversity conservation to co-develop metrics that are influential in decision-making, practical to use and meaningful across the value chain. The metric development builds upon work from the Investment Leaders Group on measuring impact and the Natural Capital Impact Group's advances on biodiversity metrics, while remaining relevant across business sectors and other players in the value chain. It was agreed to co-develop a composite 'healthy ecosystem' metric, with sub-components of biodiversity, soil and water. Key to the development of the different components of the Healthy Ecosystem framework has been the active engagement, pilot testing and financing by leading companies and members of the Natural Capital Impact Group. As such, Kering has supported the development of the Biodiversity Indicator and leveraged their Environmental Profit and Loss (EP&L) methodology while other members of the group have focused upon understanding the categorisation of, for example, healthy soil.

The metric proposed is based on the impact of a company upon the quality and quantity of biodiversity, soil and water. This paper details how this metric is constructed and provides insight into the biodiversity sub-component.

Contents

1 Introduction

In response to increasing levels of biodiversity loss and a growing recognition of the importance of a productive natural environment to business, members of the Cambridge Institute for Sustainability Leadership (CISL)'s Natural Capital Impact Group and Investment Leaders Group have expressed a need to develop clear, standardised metrics to demonstrate their progress towards reducing their impact on nature.

Specifically, there was a desire for a composite 'healthy ecosystem' metric to assess businesses' contribution to the maintenance of an ecologically functional landscape. This metric can be broken down into three sub-components of biodiversity, soil and water.

The healthy ecosystem metric builds upon the Investment Leaders Group (ILG)'s proposal for six key impact themes that an investor should consider when assessing the performance of their funds , of which 'healthy ecosystems' is one ([1]; as shown in Figure1).

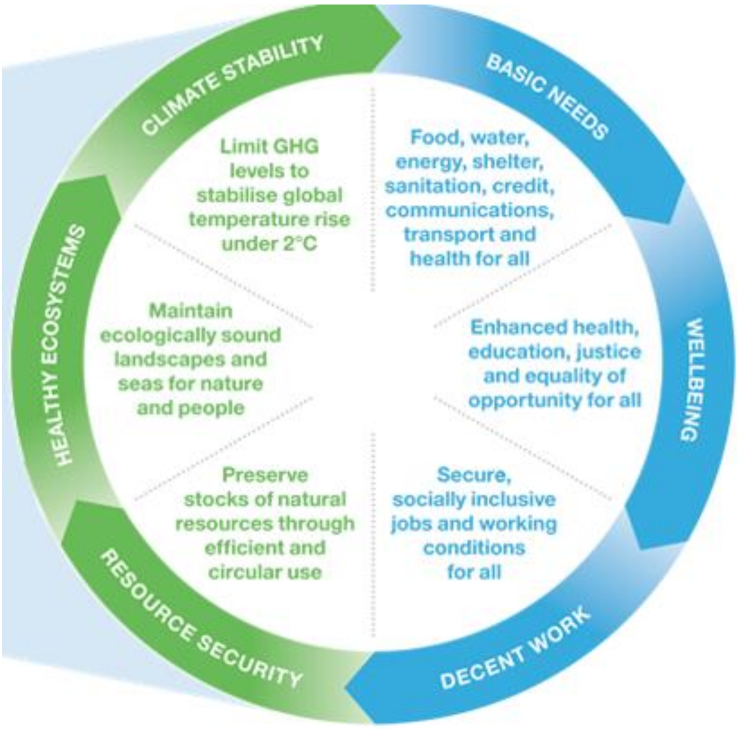

Figure 1. Six impact themes of relevance to investors, underpinned by the UN Sustainable Development Goals [1]

The metric also builds on the collaborative work between the Natural Capital Impact Group and Kering; this concluded that the ideal biodiversity metric for business should take into account the status of biodiversity, its threats, and the responses from business to abate pressure on biodiversity (described in Figure 2; [2]).

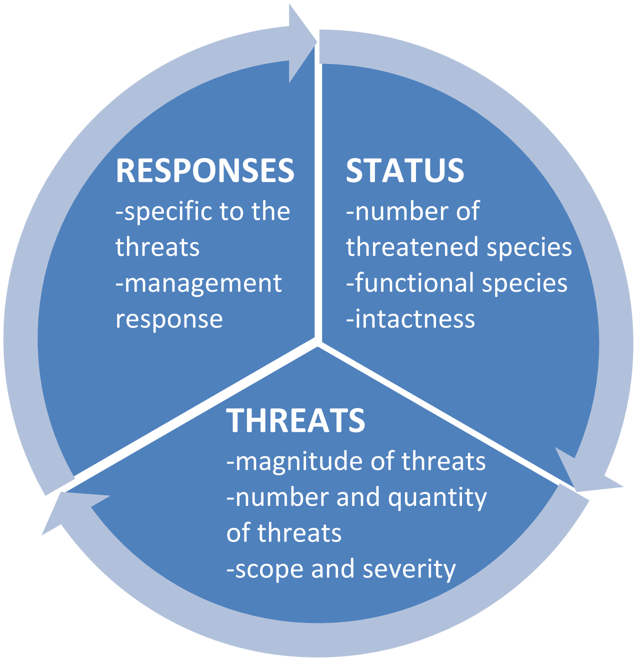

Figure 2: Possible conceptual framework for a biodiversity metric [2]

Such standardised metrics have the potential to be instrumental in shaping operational decision-making, complying with regulatory demands and responding to investor requests.[3]

1.1 Metric principles

A set of seven principles were agreed upon to guide the development of the metric (Table 1). These were established following consultation with companies, investors and experts.

Meaningful	Meaningful to business and investor communities so it can be used to drive decision-making. Methodology is clearly understood.
Measurable and comparable	Allows for comparison across geographies and time.
Possible to aggregate	Can be aggregated from site-level to regional and global scales.
Practical	Data is easily accessible, measurable by company or using free, globally available data. Ability to substitute better information where available
Replicable and credible	Based on a reputable scientific method.
Context based	Considers local conditions/levels to reflect ‘impact’ (beyond ‘usage’)
Responsive	Responds to changes and improvements in company activities, both in the short and long term.

Table 1: Key principles for biodiversity, soil and water metrics.

2 Healthy ecosystem metric conceptual framework

2.1 Basic framework for the healthy ecosystem metric

It was agreed that a healthy ecosystem metric should be based on the total land area of a company's operations and supply chains. It was proposed that this metric would be subject to further refinements to account for the impacts upon the quantity and quality of biodiversity, soil and water. The metric development has therefore focused on identifying spatially explicit measures that can be mapped against a company's land area.

It was proposed that this metric should be flexible enough to be applied at different levels of granularity. Companies which do not have good sight of their supply chains can use regional or national approximations but those that have better traceability can use data at a more local level.

In its simplest form, the metric can be expressed with the following equation:

$$\boxed{Impact\ on\ \boldsymbol{ecosystem} = \boldsymbol{land\ area} \times (impact\ on\ \boldsymbol{biodiversity} \times \boldsymbol{soil} \times \boldsymbol{water})}$$

Equation 1

The impact of companies on each of the three natural capital elements can be defined as a function of changes in its quality and quantity (summarised in Table 2). It is proposed that changes in quantity be represented through the impact of the land use; whereas impact on quality is represented by the current levels of biodiversity, soil health and water availability at each sourcing location (ie the ecosystem 'context').

The impact upon ecosystem quality and quantity will therefore be dependent upon three variables:

- land area
- land use type
- context.

The final metric provides a weighted land area that is adjusted for impact (measured in hectare equivalents; Ha_{Eq}), using the same approach as carbon equivalents.

In summary, for each raw material:

Impact on ecosystem (hectare equivalents; Ha_{Eq}) =	**Land area**	**Impact on soil, water and biodiversity**		
Description	Area required for supply chain/operations	Quantity of soil, water and biodiversity		Quality of soil, water and biodiversity
Measurement	Hectares (ha; tons/yield)	Land use type	Land use intensity	Ecosystem context
Data sources	Company data (or external data if unknown): • tons purchased • Yield (tons/ha)	Company data (or external data if unknown): • Land use type • Land use intensity External data: • Coefficients relating land use type and intensity to impact		Company data (or external data if unknown): • Sourcing location External data: • Conversion factor to account for ecosystem context

Table 2. Healthy ecosystem metric framework summary

2.2 Healthy ecosystem metric data requirements

The healthy ecosystem metric will comprise both company-specific and external data sources.

2.2.1 Company land area

Land area is the first data input. This is based on the area of the land required for company's direct and indirect supply chains and operations. Business surveys will be developed to enable the collection of this information, either directly in hectares or through conversion of the volumes of raw material purchased, using the formula below:

$$Land\ area\ (hectares) = \frac{Volume\ of\ raw\ material\ purchased\ (tons)}{Agricultural\ yield\ (tons\ per\ hectare)}$$

Equation 2

The data sources for agricultural yield will be based either on company data or regional averages from the United Nations Food and Agricultural Organisation (FAO),[4] depending on the company's awareness of their sourcing locations. In cases where a company has limited knowledge of its sourcing, the worst-case scenario data (e.g. data from regions of the world where the yield for a particular raw material is lowest) will be allocated; this will provide the incentive for companies to gain better understanding of their supply chain.

The metric will ensure that the volume conversions take into account the proportion of crops left in the field, multicropping practices, and loss of raw material through the production process.

2.2.2 Quantity

2.2.2.1 Company land use type

Land use is the second variable. In order to assess a company's impact on biodiversity, soil and water the healthy ecosystem metric requires information on their different land use types.

Surveys will be developed to determine the types of land use and management practices carried out by a company across different sourcing locations, which will be categorised according to six broad classifications under minimal, light or intense management.

The land use types are categorised as:

- primary vegetation
- recovering/secondary vegetation
- plantation forest (ie timber, fruit, oil-palm or rubber)
- cropland
- pasture
- urban.

Land use type can be inferred from the raw material, whereas land use intensity will require more precise management information. In cases where the company does is not able to provide this information, it will be assumed that the land use is intense.

This will provide an indication of the extent to which the quantity of the natural environment has been degraded.

2.2.2.2 Land use impact coefficients

The healthy ecosystem metric will require external data linking the impact of different land uses on biodiversity, soil and water. These relationships will be represented by 'impact coefficients', taken from peer-reviewed studies.

2.2.3 Quality

2.2.3.1 Company sourcing locations

The physical location of companies' supply chains is needed to provide context to the healthy ecosystem metric. This information will be collected through business surveys. As above, when a company does not have sight of the precise locality of its sourcing locations a worst-case scenario will be assumed, allocating a location where impact is assumed to be highest.

2.2.3.2 Ecosystem context datasets

The locality (or approximate locality) of the company's sourcing locations will be mapped against global, peer-reviewed datasets on the status of biodiversity, soil and water. These context datasets will highlight natural variations in the ecosystem and help identify hotspots of company pressure.

2.3 Variables a company can alter

There are three variables within this metric that a company has control of. This provides companies flexibility to demonstrate opportunities to reduce their impacts and improve the result of the healthy ecosystem metric. Companies may choose to adjust the following variables:

- *Land area*: either by reducing the quantity of raw materials required or by increasing the yield (ie procuring the same quantity from a smaller land area).
- *Land use type*: either by reducing the intensity of land use or changing the land use type (e.g. from plantation forest to secondary vegetation).
- *Ecosystem context*: by changing the location of raw material production to an area that is of less importance for biodiversity, soil or water.

3 Biodiversity impact sub-metric

The biodiversity impact sub-metric is the first to be developed as part of the healthy ecosystem metric. In line with the overall healthy ecosystem metric framework, the aim was to establish a sub-metric that could also be applied at different levels of granularity, with the ability to use regional or national approximations where precise data are lacking.

3.1 Introduction

Business operations and supply chains rely on biodiversity for resilience to pests and climatic events, ecosystem services, and the provision of high quality crops. Most of the pressure that businesses place on biodiversity is caused by land use change for raw material production.

The Natural Capital Impact Group reported that existing international and national initiatives, reporting standards and certification schemes tend to lack impact biodiversity metrics that are robust enough to influence decision-making or are meaningful to external stakeholders, including investors.[3] Indeed, biodiversity is often missed in corporate assessments due to the difficulty in evaluating its intrinsic value and role in maintaining ecological function and providing goods and services.[5] To resolve this issue, it was recommended that businesses focus on assessing the status of the 'stock' of biodiversity under their management.[5]

Several organisations are developing novel approaches for measuring biodiversity impact (described in Appendix A). The business use of existing biodiversity data is described in Appendix B.

The approach outlined in this paper provides a method of directly linking changes in a company's activities on biodiversity status by using readily available land use impact coefficients, combined with information on company land area. The metric therefore requires only two pieces of company information (which may be more feasible to obtain than conducting a life cycle analysis for all products a company produces). This approach can still be used in cases where companies do not have sight of their supply chain through the use of global averages.

3.2 Basic framework for the biodiversity impact sub-metric

It is proposed to characterise the impact of businesses on biodiversity by weighting a company's land area according to its effect on biodiversity quantity and quality. The impact on biodiversity quantity is assumed to be as a result of different land uses; the impact on biodiversity quality is evaluated by considering the current levels of biodiversity in a location.

In summary, for each raw material:

Impact on biodiversity (Hectare equivalents; Ha_{Eq}) =	**Land area**	**Impact on biodiversity**		
Description	Area required for supply chain/operations	Quantity of biodiversity		Quality of biodiversity
Measurement	Hectares (ha = tons/yield)	Land use type	Land use intensity	Ecosystem context
Data sources	Company data (or external data if unknown): • Tons purchased • Yield (tons/ha)	Company data (or external data if unknown): • Land use type • Land use intensity External data: • Coefficients relating land use type and intensity to impact on biodiversity		Company data (or external data if unknown): • Sourcing location External data: • Conversion factor to account for the importance of a location for biodiversity (eg a location's biodiversity richness or rarity)

Table 3. Healthy ecosystem metric framework summary

3.3 Biodiversity impact sub-metric data requirements

The following information is required that is specific to the biodiversity sub-metric:

3.3.1 Quantity

3.3.1.1 Land use impact coefficients

A review of scientifically peer-reviewed spatial approaches linking the effect of human activities on biodiversity was undertaken. Seven key approaches were selected for further study (detailed in Appendix C). A summary of how the approaches map against the key metric principles can be found in Appendix D; the justification for each criteria is summarised in Appendix E.

The 'Biodiversity Intactness Index' (BII) [6] was identified as the most appropriate approach for assessing the impact of land use on biodiversity. The BII has high applicability for aggregating across scales, scientific robustness and responsiveness to business activity compared with the other reviewed metrics. Its ability to apply across different spatial scales was considered to be valuable as it provides flexibility to companies with differing degrees of access to supply chain information.

Out of the reviewed metrics BII is the most practical to use. There is the possibility of directly applying the BII coefficients for different land use types and land use intensities to the area of company land use in order to determine their impact on biodiversity (fully described in Appendix F). It is proposed to determine the percentage of biodiversity lost from land use for each category (termed as the 'biodiversity loss coefficient') using the BII. This is described by Equation 3.

$$Biodiverstiy\ loss\ coefficient = 1 - BII\ coefficient$$

Equation 3

In addition to being published in two of the top scientific journals (*Nature* in 2015[6] and *Science* in 2016[7]), BII is used within the Planetary Boundary framework[8] for assessing the limits to biodiversity loss (which is set at 90 per cent intactness), has been reported within UN Environment Programme's Millennium Ecosystem Assessment,[9] and been applied within UK's 2016 State of Nature report that was co-authored by 50 UK Conservation NGOs and Institutions.[10] BII was defined as the most robust and meaningful indicator of biodiversity status based on its global data availability and multifaceted approach for defining biodiversity status, including data on species from different taxonomic groups in different ecosystems, facing different land use practices.[11]

It is important to note that the BII does not provide specific details on the exact composition of species in an area, but gives an overall proxy for the intactness of the ecosystem. It is also based on global data so will be less sensitive to local changes than if the model were developed for a specific region of the world.

3.3.2 Quality

3.3.2.1 Ecosystem context datasets

There are several scientifically peer-reviewed datasets describing current variation in the level of biodiversity across the globe; these can provide context to the impacts of businesses' activities on biodiversity. This represents the impact upon biodiversity quantity. Datasets include maps of threatened species distributions, the presence of Key Biodiversity Areas, and protection status (fully described in Appendix G). Businesses and experts are being consulted to determine which datasets are most appropriate for the biodiversity metric to describe ecosystem context.

4 Hypothetical results for a set of supply chains

4.1 Example calculations

Example calculations are provided to demonstrate how biodiversity impact would be measured. The hypothetical production of three raw materials from different sources that are associated with different levels of data availability is shown in Table 4 (data for biodiversity context are illustrative only). These examples demonstrate the flexibility of the metric to deliver results, even when companies do not have a full understanding of their supply chains.

Biodiversity impact (Hectare equivalents; Ha_{Eq}) =	**Land area**					**Impact on biodiversity**				**Results**
						Impact on quantity			**Impact on quality**	
Data sources	**Raw material**	**Source location**	Tons	Yield (tons/ha)	**Hectares (=tons/ yield)**	Land use type	Land use intensity	**Biodiversity loss coefficient (with 1 representing 100% loss)**	**Biodiversity context conversion factor (with 1 being most important for biodiversity)**	**Hectare equivalents= Land area ×biodiversity loss coefficient ×biodiversity context conversion**
Raw material 1, sourcing location a	Rice	Central Brahmaputra Valley, Assam, India	780	1.57	**496.82**	Cropland	Light	**0.38**	**0.6**	**113.26**
Raw material 1, sourcing location b	Rice	Assam, India (unknown locality)	540	1.33 (country average is assumed)	**406.02**	Cropland	Intense (unknown land use practices)	**0.36** (assume intense)	**0.7** (assume location with highest biodiversity)	**102.32**

Raw material 2, sourcing location a	Rubber	Mexico (unknown locality)	890	3.19 (country average is assumed	**279.00**	Plantation forest	Light	**0.27**	**0.5** (assume location with highest biodiversity)	**37.66**
Raw material 3, sourcing location a	Maize	New Zealand (unknown locality)	1200	10.82 (country average is assumed	**110.91**	Cropland	Intense (unknown land use practices)	**0.36** (assume intense)	**0.45** (assume location with highest biodiversity)	**17.97**
Raw material 3, sourcing location b	Maize	Oceania (unknown locality)	560	8.01 (regional average is assumed	**69.91**	Cropland	Intense (unknown land use practices)	**0.36** (assume intense)	**0.75** (assume location with highest biodiversity)	**18.88**
Total impact (hectare equivalent, Ha_{Eq}**)** (= sum of impacts across all sourcing locations of raw materials)										**290.11**
Company annual revenue ($)										**146,800**
Total impact/$										**1.98 x 10^{-3}**

Table 4: Example biodiversity impact calculation for a business with three raw materials from multiple sourcing locations.

4.2 Decision context

In order to reduce its biodiversity impact score for a particular raw material a company can adjust three variables:

1) Improve the ***yield*** through technological changes in agricultural practices or crop varieties in order to reduce the area of land required for its operations.
2) Reduce the ***intensity*** of its land practices (ie by changing to 'light intensity') in order to reduce its impact on biodiversity quality.
3) Move its sourcing to ***locations*** that are less important for biodiversity (ie that have lower 'biodiversity context conversion factors') to reduce its impact on biodiversity quantity.

Under a hypothetical situation where 100 tons of rice are sourced from a known location in India, the calculations below indicate the improvements that are possible for the company associated with that supply chain (table 5)

Biodiversity impact (hectare equivalents; Ha_{Eq}) =	**Land area**					**Impact on biodiversity**				**Results (relative impact on biodiversity)**
						Impact on quantity			**Impact on quality**	
Data sources	**Raw material**	**Source location**	Tons	Yield (tons/ha)	**Hectares (=tons/yield)**	Land use type	Land use intensity	**Biodiversity loss coefficient (with 1 representing 100% loss)**	**Biodiversity context conversion factor (with 1 being most important for biodiversity)**	**Hectare equivalents = Land area ×biodiversity loss coefficient ×biodiversity context conversion factor**
Current sourcing	Rice	Central Brahmaputra Valley, Assam, India	100	1.57	**63.69**	Cropland	Light	**0.38**	**0.6**	**14.52**
Reduce land use intensity to 'minimal'	Rice	Central Brahmaputra Valley, Assam, India	100	1.57	**63.69**	Cropland	Minimal	**0.27**	**0.6**	**10.32**
Improve yield	Rice	Central Brahmaputra Valley, Assam, India	100	2.12	**47.17**	Cropland	Light	**0.38**	**0.6**	**10.75**
Procure from a less biodiversity sensitive location	Rice	A low biodiversity area, India	100	1.57	**63.69**	Cropland	Light	**0.38**	**0.3**	**7.26**

Table 5. Relative impact of different sourcing locations on biodiversity, assuming 100 tons were required from each location. Changes are underlined.

The biodiversity metric is being tested by companies to ensure it is practical, relevant and delivers appropriate results.

5 Concluding remarks

There is a need for a clear, standardised 'healthy ecosystem' metric to assess businesses' impacts on the natural environment. The proposed metric consists of three sub-components: biodiversity, soil and water. These components will be assessed for impacts upon their quality and quantity.

Biodiversity has been investigated first. Impacts upon quantity are evaluated by changes in 'biodiversity intactness'; impacts upon quality are evaluated by considering the context of the sourcing location for biodiversity.

It is envisaged that this metric will incentivise companies to improve their score and thus reduce their impacts upon natural capital. This can be achieved by minimising the area of land required for operations, reducing the intensity level at which the land is managed, or changing sourcing locations to areas that have lower levels of biodiversity, soil health and water availability.

This metric continues to be developed by the Natural Capital Impact Group. The group is keen to collaborate with others in this space and to support the uptake of these metrics by companies and investors.

With simple, practical and consistent metrics companies and investors will be able to demonstrate their progress and incentivise others to benefit from reducing their impacts upon natural capital.

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Appendices

Appendix A: Summary of corporate biodiversity impact metric approaches under development

Organisation leading development	Type	Name of approach/product	Summary
International Union for the Conservation of Species (IUCN) and The Biodiversity Consultancy (TBC)	International NGO/Consultancy	A Red List based metric for biodiversity return on investment for finance credit risk and commodity companies	Metric based on changes in a species' probability of extinction (according to its IUCN Red List category) as a result of changes in the extent and severity of threats caused by investments/company activities.
I-CARE	Consultancy	Product Biodiversity Footprint	Metric that quantifies a product's impact on biodiversity across all the steps of its life cycle. Will incorporate multiple threatening processes from company activities and determine their impact on species, ecosystems and ecosystem services.
CDC-Biodiversité	Consultancy	Global Biodiversity Score	Mean Species Abundance (ratio between the observed biodiversity and the biodiversity in its pristine state) based on PBL Netherlands Environmental Assessment Agency's model of five environmental pressures (land use, nitrogen deposition, climate change, fragmentation, infrastructure/encroachment), and their impacts on biodiversity. Based on global data layers of pressure. Plans to use a Life Cycle Assessment approach to evaluate the biodiversity impact of an economic activity at the company or the product level.
World Resources Institute (WRI)	NGO	Global Forest Watch Interactive Map	Interactive website that can be used to map hotspots of risks to a supply chain from forest loss (through daily/weekly/monthly alerts) that can be combined with maps of biodiversity hotspots.
Bioversity International	International NGO	Agrobiodiversity Index	Metric that will assess: dietary diversity, crop diversity, seed genetic diversity, level of safeguarding for the future, and benefit to local livelihoods.
UN Environment 10 Year Framework for Programmes on Sustainable Food Systems (led by Nestlé)	International collaborative initiative	-	Initiative promoting the improvement and implementation of measures, standards, and biodiversity evaluation methods in agricultural systems.

Appendix B: Defining biodiversity for business

Biodiversity is a fundamental component of life on Earth, underpinning and influencing almost every product and service we value today. Business operations and supply chains rely on biodiversity for resilience to pests and climatic events, for ecosystem services, and the provision of high quality crops.[5] Most of the pressure that businesses place on the environment results from direct impacts to biodiversity through land use change for raw material production.[5] It has been recognised that such activities, coupled with increasing demands from a growing human population and the exacerbating effects of climate change, have placed global stocks of biodiversity at risk of collapse.[8]

A recent study has shown that biodiversity is often not considered in corporate assessments due to the difficulty in evaluating its intrinsic value and role in maintaining ecological function and providing goods and services.[5] To resolve this issue, it was recommended that businesses focus on assessing the status of the 'stock' of biodiversity under their management rather than the benefits from biodiversity as this is easier to ascertain and the two will be related.[5]

'Biodiversity' is a complex concept, defined by the Convention on Biological Diversity as the "variability among living organisms from all sources and the ecological complexes of which they are part, including the diversity within species, between species and of ecosystems".[12] Despite the multitude of biodiversity-related datasets available ie on forest area, species abundance, protected area coverage, threatened species status, genetic diversity; [13,14-17], and the variety of ways in which biodiversity trends can be captured (i.e. species richness, species diversity, population abundance, and extinction rates; [18,19]), they are renowned to be affected by gaps in knowledge and geographic distribution.[11] Such discrepancies have so far prevented any widespread use of a single biodiversity measure.[11]

Businesses' use of biodiversity data

In order to understand the types of biodiversity data already in use, nine businesses from the Natural Capital Impact Group were interviewed. They reported that, while helpful, international and national initiatives, reporting standards and certification schemes lacked impact biodiversity metrics that are robust enough to influence decision-making or are meaningful to external stakeholders, including investors.[3] Rather than measuring direct impact, such initiatives focus on assessing whether appropriate processes are in place to safeguard biodiversity.[3]

Three key stakeholders were identified that are involved in supporting businesses' in measuring and valuing biodiversity[3]: non-governmental organisations (NGOs), charities, and membership organisations. The report found that charities and NGOs were more likely to recommend map-based biodiversity metrics, while membership organisations tended to provide information on biodiversity through reports and risk and opportunity analyses. Charities provided the greatest variety of metrics for biodiversity; however, much of this information was developed for use by the conservation community and was therefore considered unlikely to be in a usable format for business.

Furthermore, it was identified that the information available on biodiversity was either at a very high-level (eg based on the location of national protected areas) or at the site-level; this is potentially limiting in how the information can be used. Out of the three natural elements examined in the report, biodiversity information was found to be one of the least readily available for business, and had the greatest variation in data quality.

Appendix C: Review of spatial biodiversity impact metrics

Metric	Description	Species included	Threats included	Baseline	Underlying data/method	Scale	Business application
Biodiversity Intactness Index (BII) [6]	Ratio of current native species abundance relative to native species abundance in an undisturbed habitat.	Proxy representing all species within the ecosystem	**Land use,** human population density, distance from roads (global datasets)	Pristine habitat	Modelled index based on species occurrence data (3 million records; temporal extent of data is 1984 – 2013) under different land uses and land use intensities, human population density and distance from roads.	From 1 km^2 to global	Can attribute business' land uses and management practices with precise levels of impact on biodiversity intactness. Results are directly related to business practices.
Occupied bird ranges [20]	Number of current overlapping breeding bird ranges	All wild bird species	None	None	Bird Species Distribution Maps of the World 2015, v5.0.	From 1 km^2 to global	Can assess number of birds present within the areas under business' management. Results are directly related to business land area occupied.
Missing individual Birds [20]	Loss of bird density due to Human Appropriation of Net Primary Productivity (NPP; a measure of plant productivity).	All wild bird species	**Land use**, represented by the NPP left over in a grid cell after human activities (global dataset; [21])	Pristine habitat	Comparison of current bird densities with number of birds that would be present in the originally intact vegetation cover (based on a global map of potential climatically driven vegetation classes [22] and estimates of average bird densities in different vegetation types [23]).	From 1 km^2 to global	Can assess loss of bird density due to different land uses and crop types. Results are directly related to business practices.
Regional Species loss [24]	Number of species lost due to cumulative land use in the region.	Mammals, birds, reptiles, amphibians and vascular plants	**Land use**	Pristine habitat	Model of species richness per ecoregion (WWF) as a result of different land uses (based on the 'Countryside Species Area Relationship)'.	From 1 m^2 to global	Can assess regional species loss of different taxonomic groups due to different land uses. Results are directly related to business practices.

Global Species Loss [24]	Number of species globally extinct due to cumulative land use in the region.	Mammals, birds, reptiles, amphibians and vascular plants	**Land use**	Pristine habitat	Model of species richness per ecoregion (WWF) as a result of different land uses (based on the 'Countryside Species Area Relationship), weighted by their global vulnerability score (IUCN/BirdLife).	From 1 m^2 to global	Can assess global species loss of different taxonomic groups due to different land uses. Results are directly related to business practices.
Mean Species Abundance (MSA) [25]	Ratio between current native species abundance and native species abundance in primary vegetation.	Proxy representing all species within the ecosystem.	**Land use,** fragmentation, infrastructure/encroachment, climate change, nitrogen deposition.	Primary vegetation (ie pristine state)	Model of MSA based on cause-effect relationships of different pressures types on species abundance.	From 0.5° by 0.5° resolution to global	Companies can assess their impact on the environment as a result of a range of threats based on global data. Results are not directly related to business practices.
IUCN species threat hotspots [26]	Level of species extinction-risk in a location as a result of human activities.	All species described within the IUCN Red List (over 76,000 species)	166 threats attributed to human activities.	None	Map of the extinction risk of overlapping species distributions, which can be associated with pressure caused by specific industries.	Flexible scale.	Companies can relate the production of their commodities to specific threats in the region and assess current species threat levels. Results are directly related to business practices, but currently cannot incorporate changes in land use intensity.

Appendix D: Evaluation of spatial approaches for assessing biodiversity impact

Each criteria is scored out of five:

Metric	Summary	**Meaningful** (to business)	**Measurable and comparable** (over time and space)	**Possible to aggregate** (from site to global)	**Practical** (to be calculated)	**Replicable and credible** (scientifically robust method)	**Context based** (in relation to local environment)	**Responsive** (to changes in business activity)	**Total points** (out of a maximum of 35)
Biodiversity Intactness Index (BII) [6]	Ratio of current native species abundance relative to native species abundance in an undisturbed habitat.	4	4	5	4	5	3	5	***30***
Regional Species loss [24]	Number of species lost due to cumulative land use in the region	5	3	5	3	3	3	4	***26***
Global Species Loss [24]	Number of species globally extinct due to cumulative land use in the region	5	3	5	3	3	3	4	***26***
Mean Species Abundance (MSA) [25]	Ratio between current native species abundance and native species abundance in primary vegetation.	4	4	5	3	4	3	1	***24***
IUCN species threat hotspots [26]	Level of species extinction-risk in a location as a result of human activities.	5	3	5	3	4	1	3	***24***
Missing individual birds [20]	Loss of bird density due to Human Appropriation of Net Primary Productivity (NPP; a measure of plant productivity).	2	3	5	3	4	3	3	***23***
Occupied bird ranges [20]	Number of current overlapping breeding bird ranges	1	3	5	3	4	1	1	***18***

Appendix E: Justification for scoring of each metric against key principles

Metric	Summary	Meaningful (to business)	Measurable and comparable (over time and space)	Possible to aggregate (from site to global)	Practical (to be calculated)	Replicable and credible (scientifically robust method)	Context based (in relation to local environment)	Responsive (to changes in business practices)
Biodiversity Intactness Index (BII)	Ratio of current native species abundance relative to native species abundance in an undisturbed habitat.	Not directly meaningful. A proxy for ecosystem health (not a direct measure).	Yes, over space. Can be repeated over time if data are available.	Yes	Yes, based on land use impact coefficients. Requires knowledge of business land use impact.	Yes, methodology has been used in *Science* and *Nature* journal articles (the top two scientific journals), published in 2015 and 2016. Used within the Planetary Boundary Framework, UN Environment Programme's Millennium Ecosystem Assessment and UK's 2016 State of Nature report. Defined as most robust and meaningful indicator of biodiversity status (Mace, 2005; member of the UK Government	Yes, in relation to pristine baseline conditions.	Yes, based on changes in business land use type and intensity.

						of the Natural Capital Committee).		
Regional Species loss	Number of species lost due to cumulative land use in the region.	More meaningful as directly related to presence of mammals, birds, reptiles, amphibians and vascular plants.	Yes, over space. Will require animal ranges from previous and future years in order to assess over time. May not be updated every year.	Yes	Requires technical expertise.	Published in *Environmental Science and Technology* in 2015. There is debate over the validity of the 'countryside' species–area relationships used in the analyses.	Yes, in relation to pristine baseline conditions.	Yes, based on changes in business land use type and intensity.
Global Species Loss	Number of species globally extinct due to cumulative land use in the region.	More meaningful as directly related to presence of mammals, birds, reptiles, amphibians and vascular plants.	Yes, over space. Will require animal ranges from previous and future years in order to assess over time. May not be updated every year.	Yes	Requires technical expertise.	Published in *Environmental Science and Technology* in 2015. There is debate over the validity of the 'countryside' species–area relationships used in the analyses.	Yes, in relation to pristine baseline conditions.	Yes, based on changes in business land use type and intensity.
Mean Species Abundance (MSA)	Ratio between current native species abundance and native species abundance in primary vegetation.	Not directly meaningful. A proxy for ecosystem health (not a direct measure).	Yes, over space. Will require past and future data layers to assess over time.	Yes	Requires technical expertise.	Yes, published in *Ecosystems* in 2009, and used in CDC Biodiversité's 'Global Biodiversity Score' methodology.	Yes, in relation to pristine baseline conditions.	No, results are not directly related to business practices as they are based on global data layers that do not provide direct information on individual business practices.

IUCN species threat hotspots	Level of species extinction-risk in a location as a result of human activities.	Yes, based on species extinctions.	Yes, over space. Will require past and future data layers to assess over time. May not be updated every year.	Yes	Requires technical expertise.	Yes, published in *Nature Ecology and Evolution* in 2017, and based on the IUCN Red List criteria, which is a scientifically robust methodology.	No, no context provided.	Yes, results are related to business practices, but currently cannot incorporate changes in intensity.
Missing individual birds	Loss of bird density due to Human Appropriation of Net Primary Productivity (NPP; a measure of plant productivity).	Not directly meaningful. Only describes one group of animals.	Yes, over space. Will require bird ranges from previous and future years in order to assess over time. May not be updated every year.	Yes	Requires technical expertise.	Yes, published in *Conservation Letters* journal in 2016.	Yes, in relation to baseline conditions of intact vegetation.	Yes, includes responses to different land uses and crop types, but does not incorporate land use intensity.
Occupied bird ranges	Number of current overlapping breeding bird ranges.	Not directly meaningful. Only describes one group of animals.	Yes, over space. Will require bird ranges from previous and future years in order to assess over time. May not be updated every year.	Yes	Requires technical expertise.	Yes, published in *Conservation Letters* journal in 2016.	No, does not include any context.	No, does not include responses to business practices.

Appendix F: Land use categories used in the Biodiversity Intactness Index

Level 1 land use	Predominant land use	Minimal use	Light use	Intense use
No evidence of prior destruction of the vegetation	Primary forest	Any disturbances identified are very minor (eg, a trail or path) or very limited in the scope of their effect (eg, hunting of a particular species of limited ecological importance).	One or more disturbances of moderate intensity (eg, selective logging) or breadth of impact (eg, bushmeat extraction), which are not severe enough to markedly change the nature of the ecosystem. Primary sites in suburban settings are at least Light use.	One or more disturbances that is severe enough to markedly change the nature of the ecosystem; this includes clear-felling of part of the site too recently for much recovery to have occurred. Primary sites in fully urban settings should be classed as Intense use.
	Primary Non-Forest	As above	As above	As above
Recovering after destruction of the vegetation	Mature Secondary Vegetation	As for Primary Vegetation-minimal use	As for Primary Vegetation-light use	As for Primary Vegetation-intense use
	Intermediate Secondary Vegetation	As for Primary Vegetation-minimal use	As for Primary Vegetation-light use	As for Primary Vegetation-intense use
	Young Secondary Vegetation	As for Primary Vegetation-minimal use	As for Primary Vegetation-light use	As for Primary Vegetation-intense use
	Secondary Vegetation (indeterminate age)	As for Primary Vegetation-minimal use	As for Primary Vegetation-light use	As for Primary Vegetation-intense use
Human use (agricultural)	Plantation forest	Extensively managed or mixed timber, fruit/coffee, oil-palm or rubber plantations in which native understorey and/or other native tree species are tolerated, which are not treated with pesticide or fertiliser, and which have not been recently (< 20 years) clear-felled.	Monoculture fruit/coffee/rubber plantations with limited pesticide input, or mixed species plantations with significant inputs. Monoculture timber plantations of mixed age with no recent (< 20 years) clear-felling. Monoculture oil-palm plantations with no recent (< 20 years) clear-felling.	Monoculture fruit/coffee/rubber plantations with significant pesticide input. Monoculture timber plantations with similarly aged trees or timber/oil-palm plantations with extensive recent (< 20 years) clear-felling.
	Cropland	Low-intensity farms, typically with	Medium intensity farming, typically showing	High-intensity monoculture farming,

		small fields, mixed crops, crop rotation, little or no inorganic fertiliser use, little or no pesticide use, little or no ploughing, little or no irrigation, little or no mechanisation.	some but not many of the following: large fields, annual ploughing, inorganic fertiliser application, pesticide application, irrigation, no crop rotation, mechanisation, monoculture crop. Organic farms in developed countries often fall within this category, as may high-intensity farming in developing countries.	typically showing many of the following features: large fields, annual ploughing, inorganic fertiliser application, pesticide application, irrigation, mechanisation, no crop rotation.
	Pasture	Pasture with minimal input of fertiliser and pesticide, and with low stock density (*not* high enough to cause significant disturbance or to stop regeneration of vegetation).	Pasture either with significant input of fertiliser or pesticide, or with high stock density (high enough to cause significant disturbance or to stop regeneration of vegetation).	Pasture with significant input of fertiliser or pesticide, *and* with high stock density (high enough to cause significant disturbance or to stop regeneration of vegetation).
Human use (urban)	Urban	Extensive managed green spaces; villages.	Suburban (eg gardens), or small managed or unmanaged green spaces in cities.	Fully urban with no significant green spaces.

Table 6. Land use categories [27]

Predominant land use	**Additional land use description**	**Land use intensity**	**Summary**	**Biodiversity intactness coefficient (with 1 representing 100% intactness)**	**Biodiversity loss coefficient (=1 – biodiversity intactness coefficient)**
Primary vegetation	-	Minimal	Presence of a trail or path, hunting of species of limited ecological importance.	1	-
		Light	Primary sites in suburban settings.	1.01	-
		Intense	Primary sites in fully urban settings.	1.054	-
Secondary vegetation	Mature secondary	Minimal	Presence of a trail or path, hunting of species of limited ecological importance.	1.016	-
	Mature secondary	Light/intense	Secondary (ie reforested/restored) sites in suburban/urban settings.	1.171	-
	Intermediate secondary	Minimal	Presence of a trail or path, hunting of species of limited ecological importance.	0.908	0.092
	Intermediate secondary	Light/intense	Secondary (ie reforested/restored) sites in suburban/urban settings.	0.901	0.099
	Young secondary	Minimal	Presence of a trail or path, hunting of species of limited ecological importance.	0.844	0.156
	Young secondary	Light/intense	Secondary (ie reforested/restored) sites in suburban/urban settings.	0.799	0.201

Plantation forest	-	Minimal	Extensively managed or mixed timber, fruit/coffee, oil-palm or rubber plantations, native tree species are tolerated, which are not treated with pesticide or fertiliser, and which have not been recently clear-felled.	0.808	0.192
	-	Light	Monoculture fruit/coffee/rubber/timber/oil palm plantations with limited pesticide input, or mixed species plantations with significant inputs, and no recent clear-felling.	0.731	0.269
	-	Intense	Monoculture fruit/coffee/rubber/timber/oil palm plantations with significant pesticide input and extensive recent (< 20 years) clear-felling.	0.606	0.394
Cropland	-	Minimal	Low-intensity farms, with small fields, mixed crops, crop rotation , little or no inorganic fertiliser use, little or no pesticide use, little or no ploughing, little or no irrigation, little or no mechanisation.	0.731	0.269
	-	Light	Medium intensity farming. Organic farms in developed countries often fall within this category, as may high-intensity farming in developing countries.	0.619	0.381
	-	Intense	High-intensity monoculture farming.	0.637	0.363
Pasture	-	Minimal	Pasture with minimal input of fertiliser and pesticide, and with low stock density.	0.782	0.218
	-	Light	Pasture either with significant input of fertiliser or pesticide, or with high stock density.	0.706	0.294
	-	Intense	Pasture with significant input of fertiliser or pesticide, *and* with high stock density.	0.629	0.371
Urban	-	Minimal	Extensive managed green spaces; typically in villages.	0.96	0.04
	-	Light	Suburban (eg gardens), or small managed or unmanaged green spaces in cities.	0.653	0.347
	-	Intense	Fully urban with no significant green spaces.	0.498	0.502

Table 7. Biodiversity intactness of different land use categories [6]

Appendix G: Potential datasets for providing biodiversity context

Dataset	Source(s)	Summary	Relevance to biodiversity context	Data restrictions for commercial purposes
Species richness/threatened species richness	Species range maps for species assessed by the International Union for the Conservation of Nature [28] and BirdLife International [29]	Number of species per grid cell. Range maps are available for approximately 51,000 species.	Describes the total number of species present but does not provide any context as to how important these species are to the ecosystem or whether they are likely to go extinct if lost from this local area.	Yes
Species endemicity/rarity	Species range maps from the International Union for the Conservation of Nature [28] and BirdLife International [29]	Measure of the contribution of a location to the species entire range, taking into account all species present in this location. Range maps are available for approximately 51,000 species.	Represents the 'quantity' of unique biodiversity that may go extinct as a result of degradations in habitat quality.	Yes
Key Biodiversity Areas (KBAs)	BirdLife International and KBA Partnership [30]	Global map of KBAs. Sites qualify as global KBAs if they meet one or more of 11 criteria, clustered into five categories: threatened biodiversity, geographically restricted biodiversity, ecological integrity, biological processes, and irreplaceability.	The proximity of business activities to KBAs or the number of KBAs within a region could be a useful way to weight impact. The closer to a KBA, the higher the likely impact. KBAs include a wide range of important characteristics, which describe 'biodiversity importance' in a more holistic manner than single-characteristic maps (eg species richness). NB It is a less accurate measure than species richness or rarity as KBAs are only found in specific locations, whereas species range maps have uniform	Yes

			coverage.	
Protection status of the ecoregions of the world	World Database of Protected Areas [31], ecoregions of the world [32] and tree coverage maps in forested ecoregions [33].	Proximity of ecoregion to 50% protection status.	The further the ecoregion is from the target of being 50% protected, the more likely that the business will have a greater negative impact in this area. NB Protection status is not directly related to biodiversity richness or rarity.	No, Excel sheets containing the protection status of all ecoregions of the world can be freely downloaded.
Human Footprint index	Updated in 2016 by Venter *et al.* [34]	Map of human pressure on the environment, including data on infrastructure, land cover, human access into natural areas from 1993-2009.	The higher the human footprint, the less likely that there will be high levels of biodiversity in this area. Businesses may have a lower impact in areas with high human footprint. NB High human pressure is not directly related to low levels of biodiversity richness.	No, can be freely downloaded (http://www.nature.com/articles/sdata201667)
Biodiversity hotspots	Critical Ecosystem Partnership Fund (2016)	Map of 36 biodiversity hotspots across the globe. To qualify as a hotspot, a region must meet two strict criteria: it must contain at least 1,500 species of vascular plants (> 0.5 percent of the world's total) as endemics, and it has to have lost at least 70 percent of its original habitat.	This data layer combines information of human pressure and biodiversity richness. The proximity of business activities to a hotspot or the number of hotspots within a region could be a useful way to weight impact. The closer to a hotspot, the higher the likely impact. NB It is a less accurate measure than species richness/rarity as hotspots are only found in specific locations, whereas species range maps have uniform coverage.	No, can be freely downloaded (http://www.cepf.net/where_we_work/Pages/default.aspx)
Global Environment Facility (GEF) Benefit Index for biodiversity Resource Allocation framework	Global Environment Facility [35]	Developed from sub-national data (at the ecoregion level) and applied at the country level. The index is based on: a) represented species, b) threatened species, c) represented ecoregions, and d) threatened ecoregions.	Combines multiple sources of biodiversity information. Draws on work by the scientific community and data compiled by various organizations, including the World Wildlife Fund, Conservation International, The World Conservation Union (IUCN), Birdlife International and FishBase.	Yes