Towards a Framework for Defining and Measuring Changes in Natural Capital

Working Paper 1

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Natural Capital Committee

Introduction

The goal of this working paper is to clarify the meaning of ‘natural capital’ for use in the Natural Capital Committee’s (NCC) work and to explore the development of a set of metrics for measuring changes in natural assets.

This work was introduced in the NCC’s first State of Natural Capital Report and it will feature prominently in the Committee’s second report to the Economic Affairs Committee due in Spring 2014.

Use of the term ‘natural capital’ is increasing in both the literature and in policy circles, often carrying a plethora of different meanings. For the NCC to succeed in advising Government on whether certain natural assets are at risk of being used unsustainably and how action to conserve and enhance natural assets should be prioritised, we need to develop the ‘natural capital’ *concept* into something tangible and measurable that can be applied in practice. This is a complex task and this working paper sets out the Committee’s thinking thus far, focusing in particular on:

1. Defining natural capital for the Committee’s use in practice.

2. Developing a conceptual framework to enable consistent analysis of changes in the natural capital assets and their values. This is an essential step underpinning all of the Committee’s work.

3. Identifying the main natural capital stocks, the ‘major land-use categories’ used for measurement purposes, the goods that are produced and the values derived from those goods.

4. Developing a set of metrics that measure stocks of assets in such a way that it is possible to estimate how goods (and ideally their value) might change with changes in the assets. This will then inform the development of natural capital monitoring programmes.

5. How to identify thresholds and aspirational targets for natural capital assets and the provision of goods to inform assessments about whether they are being used sustainably.

6. How to approach measuring degradation and enhancement of natural capital assets.

Each of these issues is discussed below and the conclusions are summarised. Note that this working paper is focuses on how to approach the categorisation and measurement of changes in natural capital. How those changes are then valued is the topic of forthcoming NCC working papers.

1. Defining natural capital

The starting point for the conceptual framework needs to be robust definition of natural capital. In the Committee's first State of Natural Capital Report, the following definition was given:

> *"Natural capital refers to the elements of nature that produce value or benefits to people (directly and indirectly), such as the stock of forests, rivers, land, minerals and oceans, as well as the natural processes and functions that underpin their operation". (NCC 2013)*

In other places, the Committee has stated that:

> *Natural capital refers to the elements of nature that produce value (directly and indirectly) to people, such as the stock of forests, rivers, land, minerals and oceans. It includes the living aspects of nature (such as fish stocks) as well as the non-living aspects (such as minerals and energy resources). Natural capital underpins all other types of capital (man-made, human and social) and is the foundation on which our economy, society and prosperity is built. By combining different forms of capital, we are able to enjoy a huge variety of benefits; ranging from the food we eat and water we consume in our homes to outdoor experiences and improved health to name but a few.*

Several previous treatments have equated natural capital closely with ecosystem services (e.g. Kareiva *et al.* 2011), with ecosystems (Dasgupta 2010) or with biodiversity (TEEB 2010). We propose that it is: a stock (rather than the flow of ecosystem services it provides); it includes biotic and abiotic elements (as opposed to only biodiversity); and these need not be interacting, as is implicit in the definition of ecosystems[1].

In simplest terms, based on the assumption that an economy's assets also comprise (i) *produced or manufactured capital* (roads, buildings, machines) and (ii) *human capital* (health, knowledge, culture and institutions), then *natural capital* is the third element that underpins all economic activity. It includes natural resources in air, water, land and below-ground. Crucially, it also includes the interactions and processes that are involved in nature's own capacity to persist, based on physical, biological and chemical processes (e.g. weathering, the water cycle, evolution, nutrient cycling, recruitment and ecological interactions).

We consider that all human welfare results from the use of these three kinds of capital; natural capital is distinguished by being available without human intervention of any kind, although for it to contribute to welfare and production there is almost always the need for some input of human or produced capital.

Barbier's (2013) account of Natural Capital adopts a similar view:

[1] The Convention on Biological Diversity defines an ecosystem as 'a dynamic complex of plant, animal and microorganism communities and the non-living environment, interacting as a functional unit'

> *In sum, the term “natural capital” is now frequently employed to define an economy’s environment and natural resource endowment – including ecosystems. Humans depend on and use this natural capital for a whole range of important benefits, which are vital to our health, sustenance and enjoyment of life. For all these reasons, our natural wealth is extremely valuable. But unlike skills, education, machines, tools and other types of human and reproducible capital, we do not have to manufacture and accumulate our endowment of natural assets. Nature has provided this endowment and its benefits to us as part of humankind's common heritage; we have not had to create these assets ourselves.*

Natural assets in decline pose a potential risk to society. Information on the status, trends and costs of recovery and/or replacement of natural assets are therefore of importance to governments, society and businesses, so the development of metrics is fundamental to the NCC’s work. A first consideration is whether the assets are renewable or non-renewable. If they are non-renewable, then the main management issue is whether the change over time is at an appropriate rate, or whether the resources will last a long time, or are substitutable. If they are renewable, the main management concern is whether the rate of depletion is less than the rate of regeneration, or is substitutable. In either case, the causes and consequences of loss of natural capital should be recorded and managed using appropriate monitoring and accounting methods.

Natural capital therefore includes all elements of the environment, including natural resources, that provide benefits to people now and in future (as well as elements that with management might produce fewer disbenefits). But some elements of natural capital are not subject to anthropogenic influence (whether intended or not), and so are excluded from a record of natural capital on pragmatic grounds. So, the items included in that record will have all of the following characteristics:

A. Be changing or likely to change in measurable levels over policy-relevant timescales (decades);

B. Have some actual or potential relevance to human welfare, now or in the future; and

C. Be plausibly subject to management by people in some way to restore or recover, or to restrict use to non-significant rates of loss, or for use by future generations.

Some exclusions from our record are, therefore, are as follows:

- *The sun* provides energy and every part of life on earth is dependent on it. But it is deteriorating at a rate that is barely measurable, and there is nothing that can be done to recover or restore it.

- *Mountains* provide many sources of value ranging from hydro-electric power potential, recreation, aesthetics, microclimates etc., as well as many disbenefits. The mountains themselves are not usually changing at rate that materially affect human wellbeing and cannot be restored or managed , although the ecosystems that they harbour may change and these should be incorporated into the metrics.

- *Volcanoes* occur and erupt intermittently in time and space, and to some extent this can be predicted and measured. Volcanic eruptions have measurable benefits and disbenefits. But there is no realistic means to intervene to manage them, although it is possible to manage exposure to them, to a degree at least.

- Flows from *deep sea vents* generate chemicals and minerals and potentially include forms of life with novel biochemical pathways. While there is some early prospecting and an increasing interest in their potential, they are inaccessible and impossible to manage.

- *Clouds* are arguably part of the atmosphere, and they do have measurable benefits (rain, controlling insolation). They can be managed to a degree, for example through cloud whitening and seeding. But they change too fast to be meaningful for policy, at least at the moment.

With these issues in mind, the NCC proposes that Natural Capital should be defined as:

> *The elements of nature that directly and indirectly produce value or benefits to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions[2].*

2. Developing a Conceptual Framework

This definition of natural capital has formed the basis of our conceptual framework. The links between natural capital and the benefits it provides are complicated, yet critical to clarify in order to develop metrics. In common with the approach taken in the UK National Ecosystem Assessment (UKNEA), we recognise the following elements:

- There is a set of natural capital *stocks* (the assets) (e.g. clean air, soil, woodland, species).

- Each natural capital stock may provide one or more *services*; these are outputs or features of each stock (e.g. freshwater, crops, trees, wildlife).

- Services, often combined with 'other capital inputs', can be used to produce *goods*. Goods are what people receive and use from natural capital stocks (e.g. good health, timber, food, nature appreciation). Goods need not be physical (such as good air quality or recreation). In economic terms, nature (natural capital) can be considered as yielding productive inputs which, when combined with produced and human inputs, generate goods that provide benefits of value to society, (see also Edens & Hein 2013).

- 'Goods' are consumed / used and provide *benefits* (to people) which can be *valued* (often in monetary terms). Natural capital stocks provide many potential services with different benefits and values. These relationships may change over time and place, for example the value of a bottle of water changes with circumstances, and according to the beneficiary. Benefits are measured in an aggregated manner, recognising that

[2] Definitions of each are included in the annex

there is substantial variation among different groups of beneficiaries, over time, place and circumstance.

In principle, we would like to measure natural capital stocks and link them to current and future values, as well as features that indicate their own sustainability. There are several practical difficulties in doing this:

1. Stocks of natural capital are dispersed, interconnected and dynamic. They are difficult to circumscribe and therefore to count or measure. For example, woodlands and soils both differ in terms of structure and composition, and this, as well as their location, substantially affects their own functions as well as their values to people. There are, albeit limited, uses for adding up the total quantity (area) of woodland but quantity is certainly not a meaningful metric for soils, which has significance mostly in terms of its composition and functions. Adding together quantities of soil and of woodland would be meaningless and it would therefore be difficult to develop metrics that are comparable across different stocks.

2. Part of the value of natural capital lies in these dispersed and interconnected characteristics, and a key feature is the potential for natural capital to fulfil different functions, and to function differently under changed circumstances. Use and values for natural capital stocks may be different in future compared to those they hold today. Therefore, by adopting a formulaic approach to the measurement of natural capital, one runs a serious risk of missing the future significance of some of its components.

3. Natural capital stocks provide multiple values that are interdependent and interacting in ways that are currently very difficult to reflect effectively in any accounting process given existing data.

In common with the UN SEEA (United Nations Statistical Division 2013), we propose to use a set of *major land-use categories*[3] as accounting units for natural capital. It is important to recognise that these are not an adequate representation of natural capital, but they are sufficient for current purposes, are measureable and can be linked to the provision of goods / benefits (we have some understanding of how management of these land-use classes impacts on the provision of goods and benefits).

In practice, these land use categories are areas of land and sea mapped according to their biophysical characteristics and the nature of recent human management within them. The major land-use categories define areas within which there is some degree of substitutability in the manner in which they provide services or natural capital inputs. Thus, there is expected to be rather little substitutability between areas classified as ‘freshwaters’ compared to areas classified as woodlands, but there should be substantially more (but certainly not complete) substitutability among areas classified as woodlands; this substitutability will be more relevant to the delivery of some benefits than others. This assumption is an important part of the decision to use the major land-use categories. Another assumption is that they will represent natural capital units in distinctive ways. .

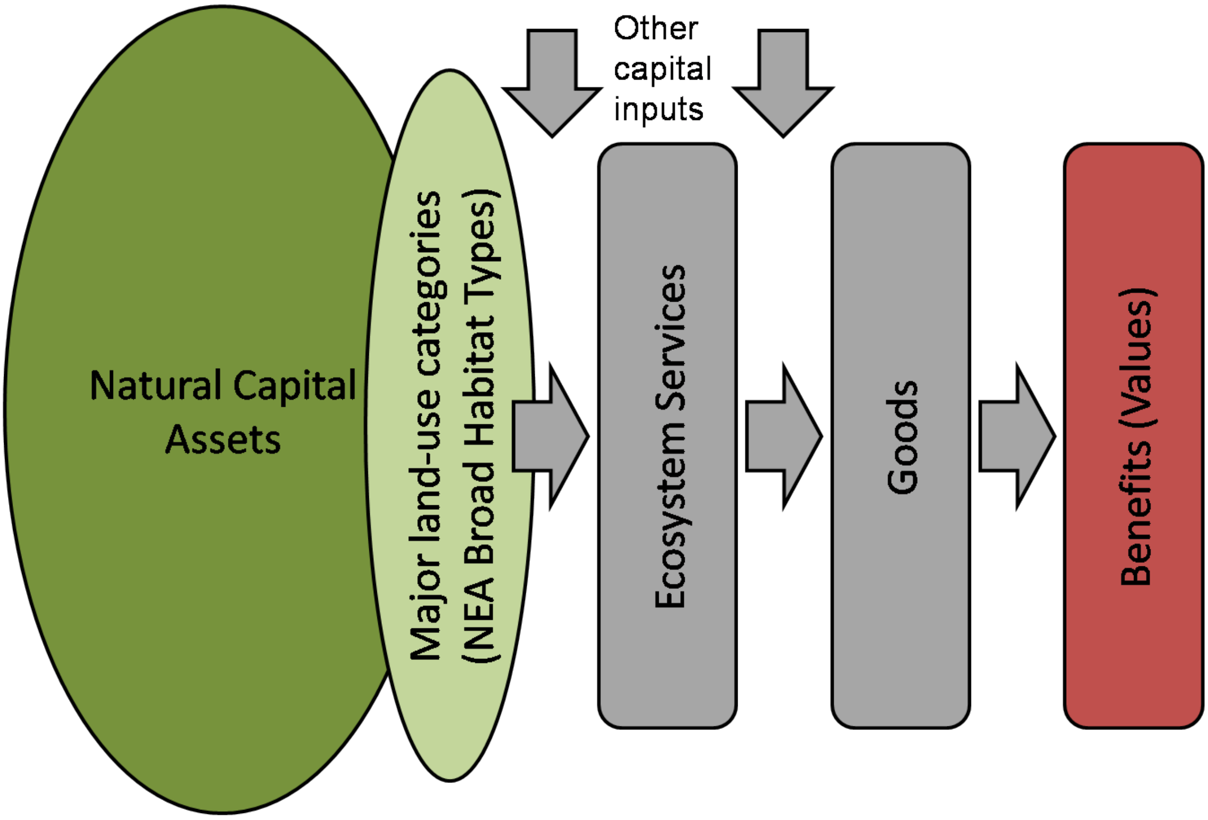
[3] By ‘major land-use categories, we mean the Board Habitat types as used in the UK National Ecosystem Assessment. SEEA refers to these are ‘accounting units’.

We use the eight Broad Habitat types from the UKNEA as land-use categories, recognising that these include terrestrial, freshwater and marine habitats. The UK Broad Habitat types are mapped to these categories and we have baseline data from the UKNEA itself. There is some evidence from which natural capital assets may be linked to the Broad Habitats as well as to benefits, starting with the UKNEA work, and continuing in National Ecosystem Assessment Follow-On (NEAFO).

These habitat types are spatially distinct and additive areas of the UK (i.e. they sum to the total land / sea area). They have some parallels with what many ecosystem service assessments refer to as 'ecosystems' (Hein *et al.* 2006; Nelson *et al.* 2009), that is, spatially defined areas of the landscape such as wetland or a river catchment, where multiple ecosystem services can be mapped and measured.

However, unlike SEEA, we propose to use these as convenient units of measurement, not as units of natural capital, nor even as proxies for natural capital. We recognise that for some there are good correlations between these major land-use categories and natural assets. For example, the land use category of woodlands is a good proxy for the natural asset of forests and woodland, and the freshwaters land use category is a good proxy for the freshwater asset. But these spatial units miss the distributional and dynamic properties of natural capital (see above), and there is no effective surrogate for soils, fresh air and biodiversity, all of which are key components of natural capital. The eight Broad Habitat types in the UKNEA may need to be disaggregated further for the NCC's metrics work.

Figure 1. Conceptual framework.



3. Assets, land-use categories and goods/benefits: definitions for measurement purposes.

Our definition of natural capital and our conceptual framework enable us to identify the natural capital stocks, major land-use categories and benefits that are to be included in our metrics.

These three groups need to be categorised in order that metrics can be developed. We use categorisations from previous work; the UKNEA primarily, but also the wider literature, including the UN SEEA process. We define categories for natural capital assets, convenient categories for the measurement of changes in major land-use types, and for the types of goods and benefits produced. The starting list is outlined below and further detail is provided in Annex 1. As the work proceeds, these categorisations will be refined and developed.

***Natural capital* stocks** include: Species (including genetic variation), Ecological Communities, Soils, Freshwaters, Land, Minerals, Atmosphere, Subsoil assets, Coasts, Oceans, as well as the natural processes and functions that underpin their operation.

Major land-use categories are the *Broad Habitats* used in the UKNEA: Mountains, moors & heaths, Enclosed farmland, Semi natural grasslands, Woodlands, Freshwaters, Coastal margins, Marine and Urban. Some of these categories may need disaggregating for analytical purposes.

Goods / benefits are Food, Fibre (including timber), Energy, Fresh water, Recreation, Clean air, Amenity, Aesthetic, Wildlife conservation and Equable Climate. Changes in these yield changes in human well-being that, in turn, can be valued in monetary terms in most cases.

4. Metrics: developing a set of metrics that measure stocks (of assets) in a way that tells us about how benefits (and possibly values) might change.

We have set out ‘what’ our metrics should ideally measure, but what should these metrics be and what features should they have?

As discussed above, a set of metrics used by the Committee in the short-term will relate to the major land-use categories and not natural capital directly. This is a practical approach and the metrics have to be designed to be relevant to assets themselves and to benefits that derive from them, and be capable of being repeatedly measured over time to give time series data.

The relevant metrics are characteristic of each stock, major land-use categories and benefits, and they are designed to reflect how changes might impact current and future assets, goods, benefits (or values). Ideally, we would like to have three sets of metrics as described below.

1. *The metrics for natural capital stocks* should reflect the key features of each natural capital asset. Hence, for species and habitat, the obvious metrics are species

richness, abundance and distribution. For habitats, we suggest measuring area and condition. We will research basic metrics for soils, freshwaters etc. using the UKNEA as a starting point. For many other environmental assets below ground, in the air, water and sea, we refer to national monitoring for environmental quality and natural resource availability.

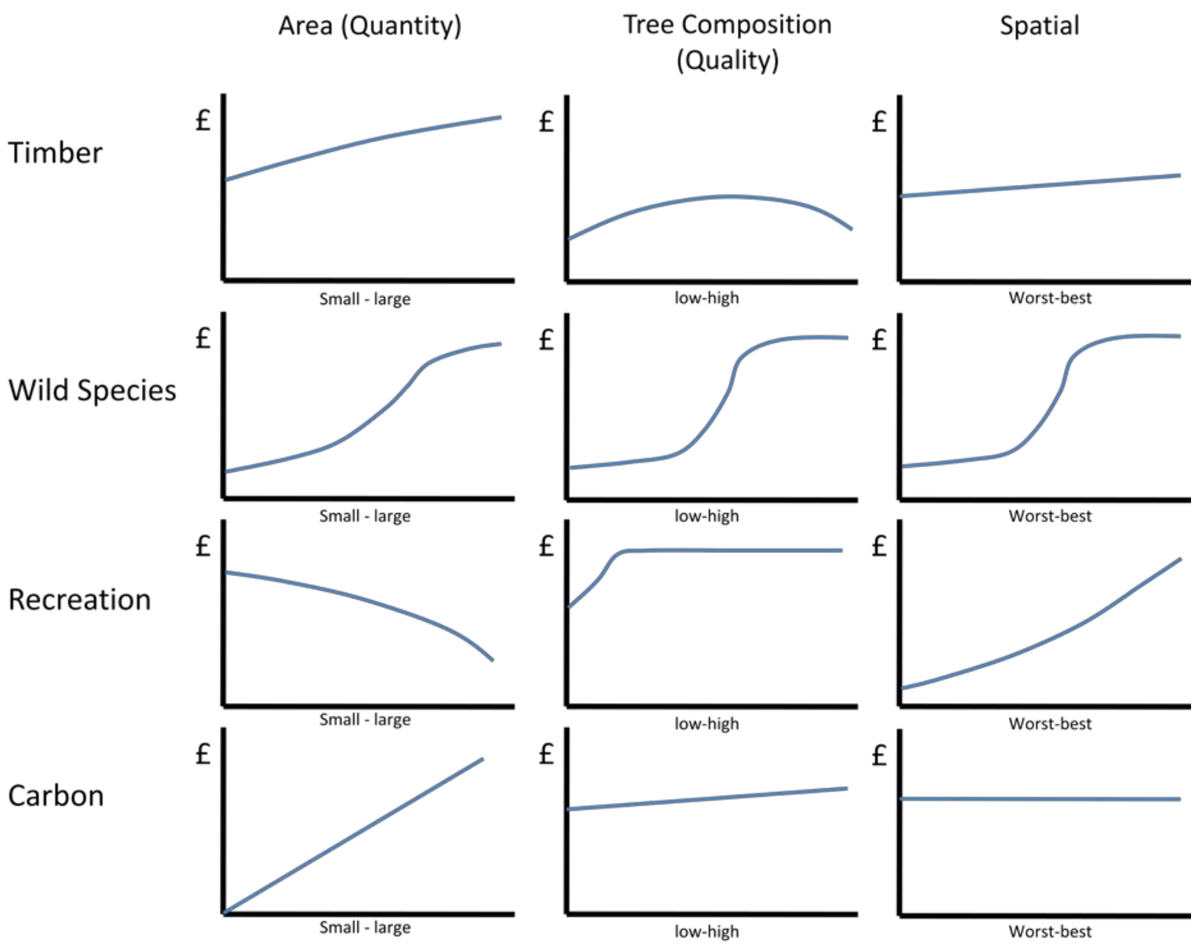
2. *Metrics for the major land-use categories* need to relate back to natural capital in some way, and on to the ecosystem services, goods and benefits that they support. This classification is based on that used in the UKNEA. The correct metric depends on the major land-use category, the natural capital elements and the benefits that are delivered. For example, in the woodlands land use category, the principal natural assets are trees, other species, soils and water. The benefits are timber, wild species conservation, carbon sequestration / storage and recreation. Each of these has a different functional relationship with metrics related to area, composition (quality) or spatial configuration (location or fragmentation etc.) of woodlands. The metrics therefore may be of one, two or three of these dimensions (quantity, quality or spatial) depending on what is relevant for sustaining the asset or the benefits provided to society. Some metrics may offer negligible information on the benefits and changes in them, whereas others may carry a lot of information (see Figure 2).

   These metrics should capture the relationship between changes in the asset (and changes in the benefits) as simply as possible. The Committee's second State of Natural Capital Report publication will report on research work that relates the Broad Habitats back to natural capital, as well as to the benefits in terms of different aspects of quantity, quality and spatial configuration.

3. *Metrics for benefits* should reflect their contribution to human wellbeing, and should ideally be net of input from productive or human capital. The values can mostly be expressed in monetary terms although for wildlife benefits there are questions about whether it is possible to generate robust estimates, especially through the use of stated preference techniques.

Figure 2: Cartoon representation of how three dimensions of metrics (quantity, quality and spatial configuration) might relate to various benefits.

In this case, for example, timber values might be represented best by area and composition, wild species may need all three metrics, but carbon sequestration is adequately measured by a metric of area alone in most cases (species composition makes a very small contribution to carbon sequestered compared to say biomass).

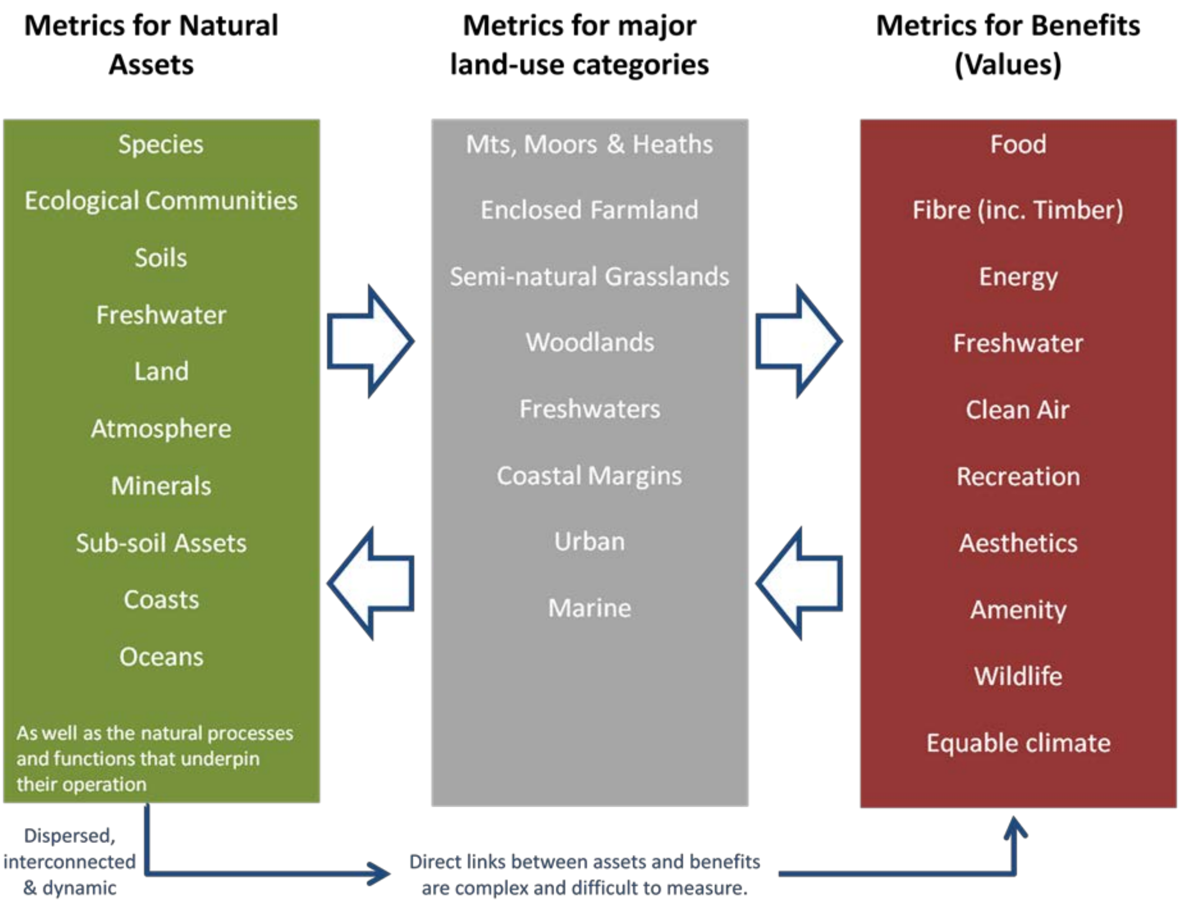


In summary therefore, the metrics required will actually be of three inter-related kinds. The first, which may be difficult to populate with data but cannot be ignored shows ***natural capital itself***, its status and trends measured over time. The second will show changes in **major land-use categories** using metrics that (a) reflect natural capital itself, and (b) assets that contribute most to benefits. The third, metrics for benefits, will show the changes in values (usually monetary) of different kinds of goods received from natural capital.

The structure of the metrics work is summarised in Figure 3. Note that the metrics for major land use categories are used both to reflect back onto elements of natural capital itself, and forwards to ecosystem services, good and benefits with their monetary values.

Figure 3: The three categories of metrics to measure status, condition or amount (in the case of benefits)

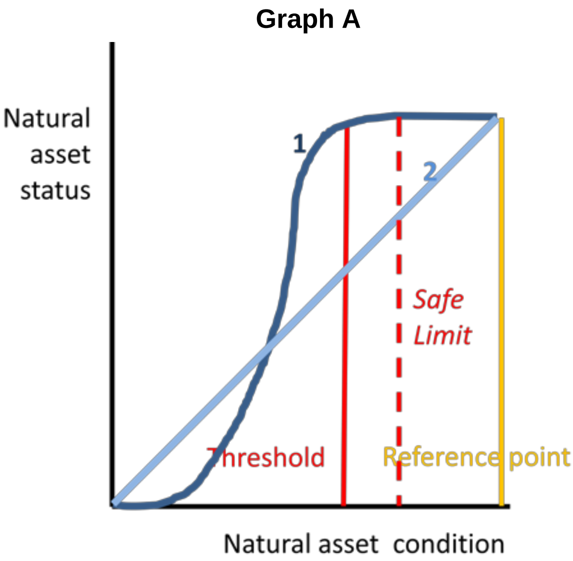
The assets, major land-use categories and benefits will have different sets of metrics. For natural assets, this will be difficult to do comprehensively. For the major land-use categories, it should be possible to do comprehensively and link to both assets and benefits. The metrics for benefits should be monetary and take account of current uses.

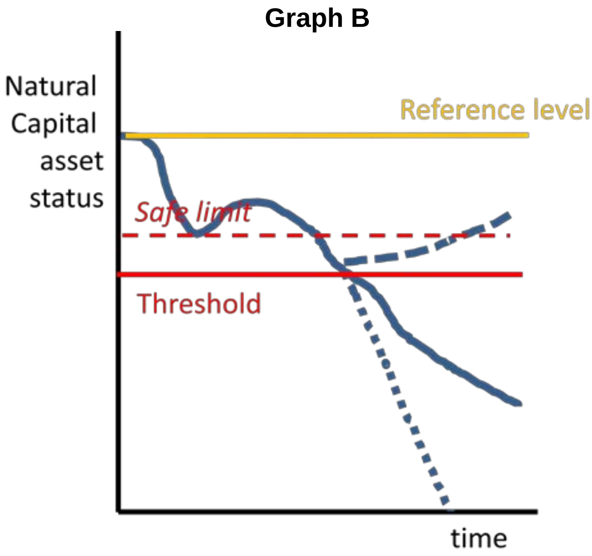


5. Thresholds: identifying limits and thresholds for natural capital to inform assessments about whether assets are being used sustainably

The three interrelated sets of metrics will need to take account of limits and thresholds for natural capital. The purpose of identifying thresholds and limits is to inform the assessment of unsustainable use. There are several distinct concepts involved which are explored below.

Figure 4: Thresholds, safe limits and reference levels for natural assets





Graph A	Graph B
Graph A depicts a stock of natural capital (e.g. wood or river). As the condition deteriorates (for example through logging or pollution), the status declines non-linearly (1) or linearly (2) (e.g. loss of area or volume). The threshold is the point at which the decline in status accelerates and/or becomes difficult to reverse. A 'safe-limit' should precede the threshold, as the latter may be hard to define. In the case of both (1) and (2), without any other information on the system, a 'reference point' can be identified, usually based on some historical or recent condition.	Graph B also depicts a stock of natural capital (e.g. wood or river) where the status is declining over time. The threshold represents the asset status beyond which recovery is impossible or very difficult (see Graph A). A 'safe limit' may be set, well before the threshold is reached. In the absence of information on thresholds, a 'reference level' indicates some historical or otherwise desirable status. The dotted line shows collapse of the asset. The dashed line shows restoration to a status within the 'safe limit'.

Natural assets may have their own thresholds as depicted in Figure 4 above, set by biophysical processes, which means that below a certain level, an asset is not self-sustaining. For example, below a certain population density, a rare species may face extinction from internal population dynamic processes; a highly fragmented habitat loses its defining features, overfishing reduces fishery stocks, a small stream may at some point be much more likely to run dry. These are *biophysical thresholds*.

A feature of these thresholds is that they can lead to abrupt and persistent change, and may exhibit hysteresis whereby the rate or path to recovery may not be the same as the rate or path of degradation. Sometimes the changes are irreversible (e.g. extinction), in other cases there is a change of state that may be extremely difficult to reverse (eutrophication in a lake) or take centuries to restore (cleared ancient woodland). Such thresholds are often difficult to define or detect before they are breached. Therefore, we define a *safe limit*: a point before a threshold is reached, which should provide some margin of safety to prevent it being crossed. Determining such a limit requires some knowledge of where thresholds lie and hence can be challenging in itself. Box 1 summarises the terminology, both for assets and benefits.

Resilience (in the ecological literature) refers to the ability of disturbed systems to recover to their former state. More resilient systems recover more quickly and more completely than less resilient systems, and non resilient systems never recover. There is, therefore, often a threshold in resilience that can be defined empirically for different natural assets, although this is generally poorly understood for many ecological systems and is an area of active research.

Box 1: Definitions and terminology

Numerous concepts and terms are used in this section of the paper and will be used by the NCC in its future work. For clarity, we define them below.

For **natural assets**:

A **reference level (or point)** is defined as the status of an asset measured at some point in the past.

A **threshold** is a discontinuity whereby a small change in a driver exerts the largest change in an attribute or state of an ecosystems; this shift is typically (but not exclusively) abrupt.

A **safe limit** is a point before a threshold. It is identified primarily based on scientific criteria. Beyond the ‘safe limit’, the risks of crossing a threshold are greatly increased.

For **goods and benefits**:

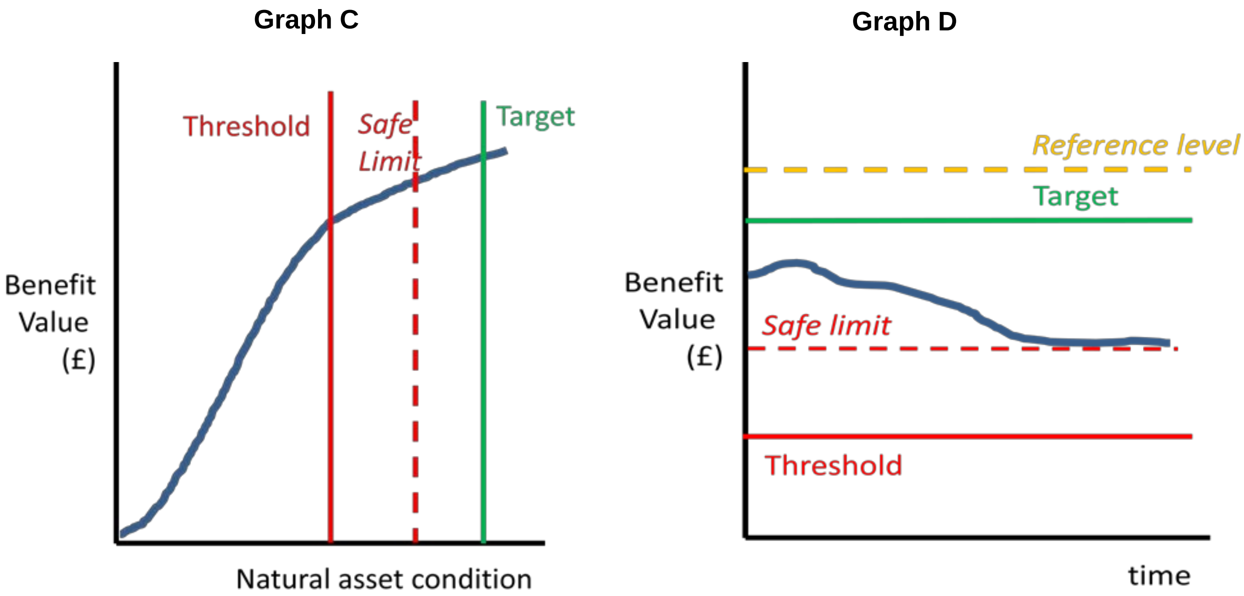
A **target** is policy determined and prescribes the socially desirable level of a particular good or benefit. These tend to be underpinned by scientific analysis but are not set with reference to a threshold. Examples include water quality targets for freshwaters and targets for levels of pollutants in the atmosphere.

A **reference level (or point)** is defined as the level of a benefit (or good) measured at some point in the past.

A **threshold** is the point at which benefits tend to zero, typically in an abrupt manner.

A **safe limit** is a point before a threshold, defined by policy and informed by science and economic analysis.

Figure 5: Thresholds, safe limits and 'targets' for benefits derived from natural assets



Graph C show how the benefits from natural capital (e.g. timber, clean water), deteriorate as the condition of the asset declines (e.g. from pollution). A 'safe limit' might be set to prevent the asset approaching a threshold for benefit delivery. The societally derived target is set to be the benefit that is required/desired and not with reference to the threshold.

Graph D shows the benefits from natural capital (e.g. clean water), deteriorating over time but being managed to be at the safe limit, which is set well before the threshold at which the benefit would collapse. The societally derived target is based on desired levels of benefits and should lie well within the safe limits. A 'reference level' may sometimes be set based on the reference level for the asset itself (Graph A & B) and this could be above or below the target.

The concepts of thresholds, limits and targets work slightly differently when analysing the *benefits* we derive from natural assets. These are depicted in Figure 5, graphs C and D.

The concept of a *threshold* for assets (as described above) is similar in the case for benefits. It is essentially a level of quantity, quality or spatial configuration that relates to the major land-use categories' ability to deliver certain benefits. For example, if water levels dropped significantly, there might be insufficient river flow supporting fisheries and hydro-electric power, or if all woodlands were small plantations there might be limited woodland bird species. There may be sharp non-linearities in the relationships between the changes in the characteristics of major land-use categories and the benefits that result, and these can be identified in the land-use type metrics.

Resilience in major land-use categories could be measured according to the same principles above, but there the recovery would be to the level that ensured the continuing benefits in the face of loss of quantity, quality or spatial features. In principle this may be less or more than the resilience for the relevant natural asset itself. For example, if the only requirement for an area of water (a lake) was for flood control, the threshold for resilience would be lower for most metrics than if it was required to maintain all other ecological functions of the lake.

Problems arise when the threshold for resilience is encountered before the management target.

For example many collapsed fisheries can be attributed to levels of harvesting (fishing) above the replacement capacity of the fish population or the ecological community of which these fish are a part. Thresholds are therefore characterised by sharp changes in the delivery of goods and benefits. The concept of 'safe limits' also applies here too.

There may also be a 'socially desirable' level of some benefits to which we aspire through the more effective management of natural capital. We refer to these as targets in Figures 4 and 5 and these are defined through policy, not by the biophysical properties of the asset (although ideally knowledge of biophysical thresholds will inform the setting of targets). Where targets don't exist, a reference level for the benefit may be required. There are targets for fisheries and forestry management, based on maximum sustainable yield, for example. There are also targets based on regulation and legislation such as a national carbon budget from the Climate Change Act (2008), the species and habitats listed under the European Union Habitats and Species Directive, and the requirements of the European Union Water Framework Directive. In addition, it would be possible to develop some simple targets for recreation or for urban green space, for example, X area within Y distance of Z% of the population.

In principle, ensuring precautionary limits are sustained or targets reached will specify a required configuration, quantity or quality of the relevant major land-use type (see Figure 2). This will come from consideration of benefits, not natural capital or the habitat units.

In summary, it is vitally important that the metrics chosen and developed are responsive to thresholds, safe limits, targets and reference levels as identified above.

6. Conclusion: measuring sustainable use, degradation and enhancements of natural capital

From all the elements above, we are optimistic that is it possible to construct a set of useful metrics. These are likely to be more advanced for the major land-use categories and goods/benefits. Some coverage of assets should be possible, particularly for species and habitats.

A key challenge for the Committee will be to report on where we think assets are not being used sustainably. Some emerging criteria for this are outlined below.

The emerging view of the Committee is that degradation and depletion occurs when:

- Any of the **natural assets** decline significantly over time and / or approach safe limits; and / or

- The metrics for the **major land-use categories** related to benefits show a decline, due to degradation of the underpinning natural assets.

Unsustainable use occurs when:

- Natural assets are continuously declining; and / or
- Thresholds or safe limits in the major-land-use categories / benefits are approached.

The approach to metrics for natural capital described above is premised on the kind of information that could reasonably be gathered for major natural assets of a country such as England. The proposals here are primarily geared towards undertaking a broad-based and inclusive assessment of natural assets and any risks posed to the benefits that they provide to people now and in future given the current status, trends and changing pressures.

Given this set of objectives it is important to emphasise that this approach cannot necessarily be generalised to other decisions about natural capital and its uses. There are many decisions made at smaller, larger and international scales that need to take account of many other, important factors that are simply not considered here. However, we suggest that the process outlined should support a broad and inclusive approach to measuring the trends in natural capital in England, can be the basis for a national risk register, and can provide a firm foundation for other systems for accounting and decision making in public and private sectors.

It is also important to recognise that certain measures and metrics do not exist at present and measurement and recording systems will need to be established, especially for the natural assets and their benefits that are not normally considered in decision-making. This particularly refers to those assets that are usually ‘taken for granted’ (clean air; water, etc.) and the benefits that flow from them. The assets and the benefit values should also be expected to change over time, sometimes quite rapidly, and any metrics approach therefore needs to refresh the basic relationships regularly. For example, carbon sequestration and storage has become a more significant benefit in recent decades due to high atmospheric CO_2 levels, and we can expect the water regulating services provided by certain soils and vegetation types to become more highly valued in an environment where there is heavier and persistent rainfall.

The work described here has not considered two other significant policy issues related to natural capital sustainability. For example, where unsustainable use is indicated, there are potentially three kinds of solutions: to cut-back on usage (reducing benefits), to find an alternative supply overseas, or to allow the asset to deteriorate potentially to nothing and forego future benefits. These issues concern England’s dependence on natural capital overseas and the extent to which certain assets are substitutable with produced or manufactured capital, or indeed whether the benefit itself can or should be foregone. The Committee hopes to look at these issues in more detail as it develops its advice to Government.

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Annex 1: Definitions of Natural Assets, Broad Habitats and Goods

Natural Assets

Note: these assets are not mutually exclusive and there is overlap between categories (e.g. soils include species, minerals, water etc). This illustrates the complexity of natural capital.

Species: All living organisms including plants, animals, fungi and micro-organisms. The product of ongoing evolutionary processes.

Ecological Communities: A group of actually or potentially, interacting species living in the same place. Groups of interacting species form distinctive assemblages interacting with their physical environment.

Soils: The combination of weathered minerals, organic materials, and living organisms and the interactions between these.

Freshwaters: Freshwater bodies (rivers, lakes, ponds and ground-waters) and wetlands. Includes water, sediments, living organisms and the interactions between these.

Land: The physical surface of the Earth and space for human activity. Includes the various landforms and processes which shape these (weathering and erosion).

Atmosphere: The layer of gases surrounding the Earth including oxygen, carbon dioxide and nitrogen used by all living organisms, and the processes which give rise to climate, weather (wind, precipitation) and temperature regulation.

Minerals: Naturally occurring, non-living substances with a specific chemical composition formed by geologic processes.

Sub-soil assets: Other non-living substances in the Earth's crust including rocks and aggregates as well as non-mineral substances such as fossil fuels.

Oceans: Saline bodies of water that occupy the majority of the Earth's surface. Includes water, sediments, living organisms and the interactions between these.

Coasts: The transitional zone between land and oceans. Includes water, sediments, living organisms and the interactions between these.

Major land-use categories (NEA broad habitats)

These follow the classification used in the UK National Ecosystem Assessment and are useful for analytical purposes because they sum to the total land area of the UK (or England in this case) and are mutually exclusive.

For some analyses, these habitat classifications may be too broad and so have been sub-divided into meaningful habitat units.

Land use category (UKNEA Broad Habitat)	Component habitats	Scope
Mountains, Moorlands and Heaths	Blanket Bog	Rainfall-fed bog in upland environments
	Mountains, Moorlands and Upland Heaths	Upland heath, montane habitats and associated wetlands (flushes, fens). Also include rock and scree habitats such as limestone pavements.
	Lowland Heath	Lowland habitats dominated by heather family or dwarf gorse species
Semi-natural grasslands	Semi-natural grasslands	All grasslands unimproved for agricultural purposes. This includes a range of grassland types.
Enclosed farmland	Enclosed farmland	Arable, horticultural land and improved grassland as well as associated boundary features e.g. hedgerows
Woodlands	Woodlands	Includes broadleaved and coniferous woodlands both natural woods and planted. (Wet woodland is included here)
Freshwaters	Standing open waters	Lakes and ponds (reservoirs and canals are considered to be manmade and therefore out of scope)
	Rivers and streams	Streams and rivers down to the tidal limit
	Groundwaters	Aquifers and significant quantities of below ground water.
	Wetlands	Lowland fens, raised bogs, swamps,

		reedbeds and floodplain wetlands
Urban	Urban	The natural environment elements of built up areas e.g. parks, gardens, towpaths, urban trees, sustainable urban drainage systems.
Coastal Margins	Coastal dunes and sandy shores	Dune systems and the upper zone of sandy shores.
	Saltmarsh	The upper zone of vegetated intertidal habitat - transition into other intertidal habitats.
	Transitional and coastal waters	Estuaries, coastal lagoons and other near shore waters
Marine[4]	Intertidal rock	Bedrock, boulders and cobbles which occur in the intertidal zone. Colonised by mussels/barnacles and seaweeds depending on exposure.
	Intertidal sediment	Shingle (mobile cobbles and pebbles), gravel, sand and mud in the intertidal zone.
	Subtidal rock	Bedrock, boulders and cobbles in the subtidal zone colonised by seaweeds (infralittoral zone) or animal communities (circalittoral zone).
	Shallow subtidal sediment	Shingle (mobile cobbles and pebbles), gravel, sand and mud in the subtidal zone.
	Deep sea bed	The sea bed beyond the continental shelf break.
	Pelagic water column	The water column of shallow or deep sea; beyond the coastal waters.

[4] The marine 'land-use type' is based on EUNIS habitat classification and proposals for Marine Strategy Framework Directive reporting. These could be amalgamated to give: intertidal, subtidal, deep sea bed and pelagic.

Goods

Note: Some goods are the product of natural capital and other capital inputs e.g. most food is prepared or processed before being consumed

Food: Plant, animal and fungi consumed by people. Both wild and cultivated sources.

Fibre: Plant and animal materials used by people for building, clothing and other objects, including timber.

Energy: All sources of energy used by people (fossil fuels, wind, tidal, wave, hydro, biomass and solar).

Clean water: Water for human use (e.g. drinking, bathing, industrial processes); a combination of quality and quantity.

Clean air: Air quality that has no adverse impact upon human health or wellbeing.

Recreation: Active enjoyment of the natural environment e.g. walking, fishing, canoeing.

Aesthetics: Passive enjoyment of the natural environment e.g. landscape appreciation and views.

Wildlife: Wild species diversity and abundance which has aesthetic and recreational value and has cultural and spiritual significance. Distinct from the natural capital assets, species and ecological communities, in that these represent the species that are significant to England and that people care about.

Protection from hazards: Natural regulation of extreme events such as flooding, drought and landslips.

Equable climate: A comfortable climate that has no adverse impact upon human health or wellbeing. The result of both global scale and local scale effects (e.g. urban cooling by trees).