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The start of a conversation on the value of New Zealand's natural capital

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The Start of a Conversation on the Value of New Zealand's Natural Capital

Sonette van Zyl and Joey Au

Office of the Chief Economic Adviser
Living Standards Series: Discussion Paper 18/03

February 2018

DISCLAIMER

This paper is one of a series of discussion papers on wellbeing in the Treasury's Living Standards Framework. The papers on [natural capital](#), [social capital](#), [human capital](#), and [wellbeing frameworks](#) are discussion papers. The discussion papers are not the Treasury's position on measuring intergenerational wellbeing and its sustainability in New Zealand. Our intention is to encourage discussion on these topics.

There are marked differences in perspective between the papers that reflect differences in the subject matter as well as differences in the state of knowledge. The Treasury welcomes comments on these papers to help inform our ongoing development of the Living Standards Framework.

In contrast, [The Treasury Approach to the Living Standards Framework](#) is a Treasury Paper, which describes the current work on the Living Standards Framework and our plans for future work.

**LIVING STANDARDS SERIES
DISCUSSION PAPER 18/03**

The Start of a Conversation on the Value of New Zealand's
Natural Capital

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- 1 NZIER: Capturing natural capital in decision making - Updated stocktake of recent literature (September 2017)
- 2 NZIER: What's the use of non-use values? (December 2017), and
- 3 Les Oxley, Mubashir Qasim (University of Waikato) and Eoin McLaughlin (University of St. Andrews): Testing Genuine Savings in NZ (2017).

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Executive Summary

Natural capital refers to all aspects of the natural environment. It includes individual assets such as minerals, energy resources, land, soil, water, trees, plants and wildlife. It also includes broader ecosystems and their services; that is, the joint functioning of, or interactions among, different environmental assets, as seen in forests, soil, aquatic environments and the atmosphere.

We have adopted the Total Economic Value (TEV) framework for how we think about the overall value of natural capital. This framework identifies the value people derive from not just using but also from not-using natural capital like the existence, bequest and option value.

We seek to provide more information about the quantity, state and value of natural capital in New Zealand, and inform decision-making by providing more quantitative information on the environmental costs and benefits of public policies.

Measuring the value of natural capital is not easy and although we have started on this journey we are still very much near the starting line. While the System of Environmental and Economic Accounts (SEEA) provides a central framework of agreed standards for preparing natural resource accounts consistent with the economic accounts it is only a partial measure of the total value of natural capital.

Overall, the key environmental indicators we looked at have been trending downwards and suggests that the overall state of the environment is declining. While the available New Zealand SEEA data are trending upwards, the existing quality and comprehensiveness of the data cannot be used usefully to inform the overall value of natural capital.

We also seek to determine whether we are on, moving away or moving closer to a sustainable development path given our focus on intergenerational wellbeing.

Models used to estimate whether a country is sustainable are hindered by the narrow breadth of good and robust data on the four capital stocks. Significant data limitations means that it is unclear whether current development is sustainable or not.

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Context

The Treasury intends that, as the Living Standards Framework (LSF) develops to reflect a comprehensive statement of the capital stocks, the information on and analysis of the value of natural capital in our society will become more comprehensive. This paper is a beginning towards this goal. It summarises the key findings from the existing literature to illuminate the main findings about New Zealand's natural capital. It is intended to act as a starting point in measuring and evaluating the value of natural capital in New Zealand.

Definition

Natural capital has recently been seen as a set of natural resources that form an asset class comparable to man-made physical and financial assets, and less tangible assets of human capital and social (and/or institutional) capital. It is primarily a stock measure, but it generates flows of goods and services of use to people and it both supplies current consumption and can be degraded by it (OECD, 2013).

Various definitions exist, such as that from the Organisation for Economic Cooperation and Development (OECD) "How's Life?" (2015): "Natural capital refers to critical aspects of the natural environment. It can include individual assets such as minerals, energy resources, land, soil, water, trees, plants and wildlife. However, it also includes broader ecosystems – ie, the joint functioning of, or interactions among, different environmental assets, as seen in forests, soil, aquatic environments and the atmosphere."

Similarly, the UK's Natural Capital Committee (2014): "Natural Capital refers to the elements of nature that produce value to people, such as the stock of forests, water, land, minerals and oceans ... providing food, clean air, wildlife, energy, wood, recreation and protection from hazards".

The Global Nature Fund (2012) defines natural capital from conventional capital definitions as "the inventory of natural resources that can be used for production of goods and services".

The Wealth Accounting and Valuing Ecosystems Services partnership (WAVES n.d.) defines natural capital to include "the resources that we easily recognize and measure such as minerals and energy, forest timber, agricultural land, fisheries and water. It also includes ecosystems producing services that are often 'invisible' to most people such as air and water filtration, flood protection, carbon storage, pollination for crops, and habitat for fisheries and wildlife. These values are not readily captured in markets, so we don't really know how much they contribute to the economy or what it would cost if we lose them".

Helm (2015) defines natural capital in more discursive terms. Capital is an input into production, which in turn produces a flow of goods and services of benefit to humankind. Natural capital is not produced by human activity, but provided by nature for free – although there may be some cost in harnessing it for human purposes; for example in catching fish from the sea, extracting minerals from the ground or collecting water and storing its potential energy. Natural capital consists of resources that may be non-renewable, in the sense that there is a fixed recoverable amount which is depleted by use (eg, subterranean oil and gas reserves) or renewable, with a potentially infinite yield at zero cost (such as the energy embodied in rivers and the wind). Some resources are more accurately described as conditionally renewable in that they are infinitely renewable if managed within limits: examples include fisheries and forests which are renewable if harvested at less than their

rate of replenishment, and the assimilation capacity of air, water and soils to absorb contaminants and wastes at levels that do not cause harm to human activities.

The precise definition of natural capital is important because natural capital is often referred to loosely in literature as if it is universally known what it is but in practice, efforts to quantify and value natural capital depend on data quality (which may be deficient) and varying assumptions and inputs that can produce quite different results.

Our working definition of natural capital mirrors the OECD’s definition with three tweaks. Our working definition:

- 1 refers to “all” aspects of the natural environment and not just the “critical” aspects
- 2 instead of saying “can include individual assets...” we say it “includes...”, and
- 3 explicitly mentions ecosystem “services”.

Natural capital refers to all aspects of the natural environment. It includes individual assets such as minerals, energy resources, land, soil, water, trees, plants and wildlife. And, also includes broader ecosystems and their services – ie, the joint functioning of, or interactions among, different environmental assets, as seen in forests, soil, aquatic environments and the atmosphere.

Adapted from the OECD How’s Life? (2015) definition of natural capital

Natural Capital and Wellbeing

Quite often when people refer to natural capital they are simply referring only to the stock of natural capital (eg, just the timber we get from trees). However, ecosystem services are what connects natural capital to people’s wellbeing. For example, a forest would be seen as an ecosystem that, not only provides timber, but also sequesters carbon, cleans the air, filters water etc. Ecosystem services flow from natural capital stocks and processes and translate to benefits that give rise to the things that societies value.

Figure 1 – Natural capital stocks and flows

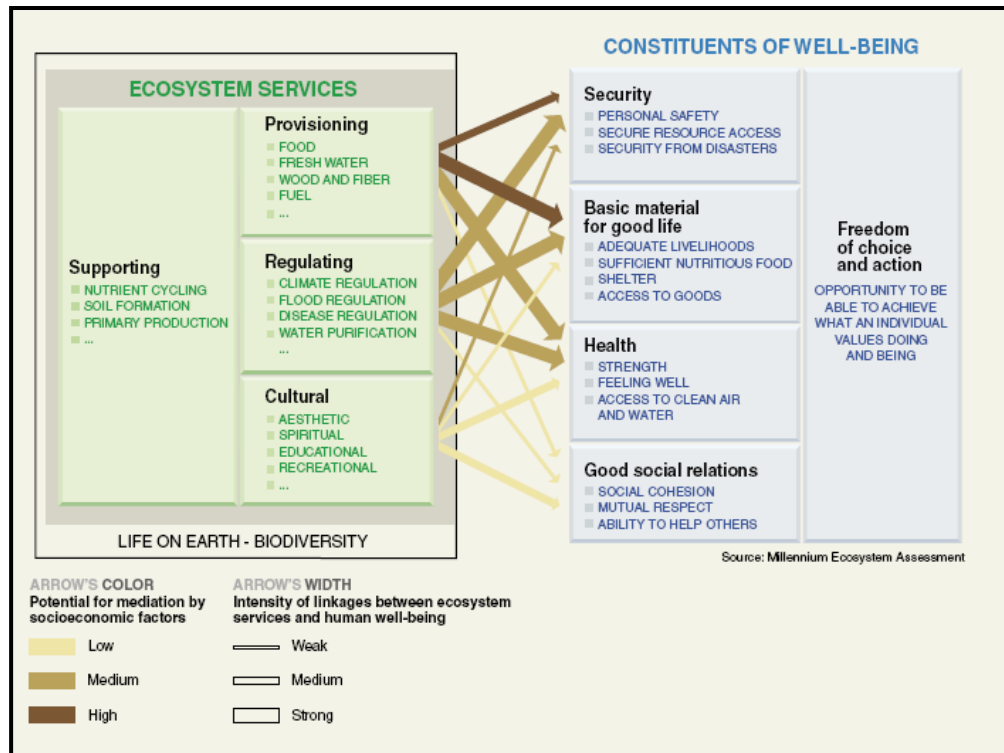


Source: Forum for the Future (2013)

The term ecosystem services has emerged relatively recently in the 1990s to bring together economic and ecological thought and formalise what was being done in a more ad hoc manner previously. It received some attention after Costanza et al. (1997) published their estimate of total worldwide value of ecosystem services and found it to be about three times the value of global gross domestic product (GDP) for the same year. Since then the United Nations (UN) initiated the Millennium Ecosystem Assessment to provide a common analytical framework that distinguishes the following types of ecosystem services:

- **Provisioning services**, supplying materials, food, fibre and energy for human use.
- **Cultural services**, supplying settings and conditions for other forms of human benefit, such as outlets for recreational, scientific and spiritual enrichment.
- **Regulating services**, such as natural controls over excessive water flows and climatic extremes.
- **Supporting services**, such as water and nutrient cycling and plant pollination that underpin a wide range of other human activity.

Figure 2 - Ecosystems and human wellbeing



Source: Millennium Ecosystem Assessment (2005)

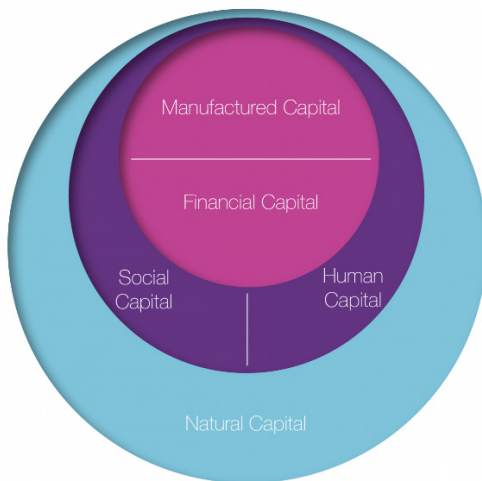
Estimating the future streams of ecosystem services and converting them to a net present value provides a measure of the natural capital from which they are derived. However, correctly identifying and quantifying all the streams of service and avoiding double counting between intermediate and final outputs has been challenging. Supporting services are sometimes omitted because of complexity and double counting issues.

Natural Capital and the Other Capitals

The economy and society do not exist independently from natural capital – they exist within it, with air, water, land and habitat all providing a variety of environmental functions and life-support mechanisms that enable growth and development.

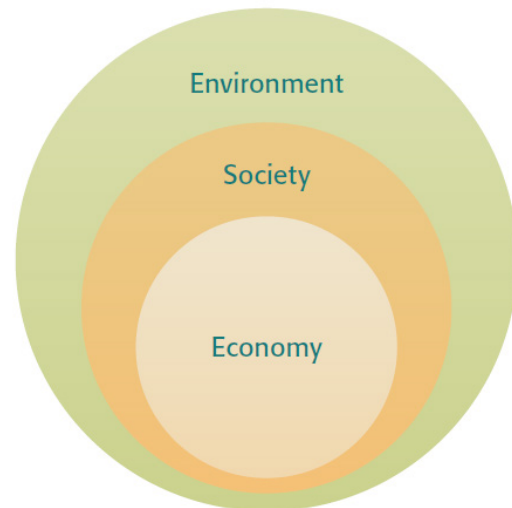
Figure 3 – Interrelationships between the capitals

The Five Capitals Model – a framework for sustainability



Source: Forum for the Future (2014)

Relationship between the environment, society, and the economy



Source: Stats NZ (2008)

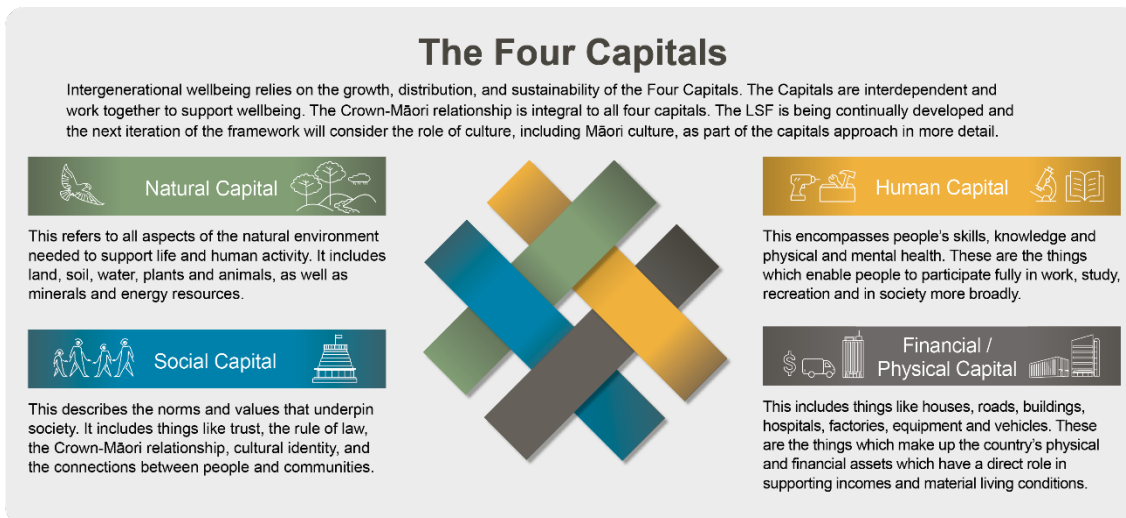
Many of the benefits of natural capital (notwithstanding the value it has in and of itself) come from its role in the production of other capitals which, in turn, contribute to people's material wellbeing and quality of life now and in the future.

For example, natural capital generally plays a key role in economic production – providing the energy and raw materials for economic activities ranging from manufacturing to agriculture and tourism. Natural capital is also key to human capital, including through its role in the provision of water and food, fuel to heat homes and a healthy living environment for people. Ecosystems also provide important sink functions (eg, by storing pollution, waste and carbon) as well as protection from natural hazards (such as ultra-violet rays or flooding). Similarly, competition for scarce natural resources or insecurity around the future provision of food, water, minerals or energy can threaten social capital and be a source of conflicts within and between countries. (OECD, 2015).

Sustainability

While we mainly focus on natural capital in this paper it is worth noting again that natural capital is only one of the four capitals we rely on for intergenerational wellbeing.

Figure 4 – The Treasury’s Living Standards Framework



Furthermore, the ultimate purpose of public policy is to improve the lives of people now and into the future (Au & Karacaoglu, 2015) and decreases in one capital stock do not necessarily represent a decrease in intergenerational wellbeing especially if it leads to improvements in other capitals. This focus on intergenerational wellbeing is known in the academic literature by the concept of “sustainability” (or sustainable development).

One of the first publications to explore the concept of *weak* sustainability was Pearce, Markandya and Barbier (1989) in *Blueprint for a Green Economy*. They define sustainable development as a situation where wellbeing for a given population is not declining, or preferably is increasing over time.

They state that this requires that each generation passes on an undiminished stock of total capital to the next generation, meeting a requirement for intergenerational fairness and non-declining consumption over time. They note arguments over the extent to which a decline in natural capital (eg, a loss of forests) can be compensated for by an increase in produced or human capital, leading to two cases for this intergenerational rule:

- Sustainable development requires non-declining total wealth (weak sustainability).
- Sustainable development requires non-declining natural wealth (strong sustainability).

Pearce et al. (1989) provide four reasons why we might need to impose rule (2 – strong sustainability) rather than rule (1 – weak sustainability) for welfare to be non-declining. These are:

- lack of sufficient substitutability
- irreversibility
- uncertainty, and
- intra-generational equity, on the grounds that the poor are often more adversely affected by poor environmental quality than the rich.

There are indications in the text that Pearce et al. (1989) thought that constraint (2) should always be taken account of in some way, as sustainability could not be assured regardless of the state of a country's natural capital. For example, on page 48 they note: "...there are strong reasons to think of sustainable development as involving...that the stock of environmental assets as a whole should not decrease". This is more consistent with the idea of strong sustainability than weak sustainability. Later on, they propose implementing this at the level of programmes of investment by requiring shadow projects, which offset the value of environmental losses.

Other definitions/approaches:

- Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (WCED 1987, p.43).
- An alternative approach [to sustainable development] is to focus on natural capital assets and suggest that they should not decline through time. (Pearce et al. 1989, p.37).
- Pezzey (2004) defined a development path for an economy to be sustainable if current utility does not decrease at any point along the path.
- Dasgupta and Mäler (2001) use a less stringent condition, that a path is sustainable if social welfare (the present value of utility) does not decline at any point along the path.

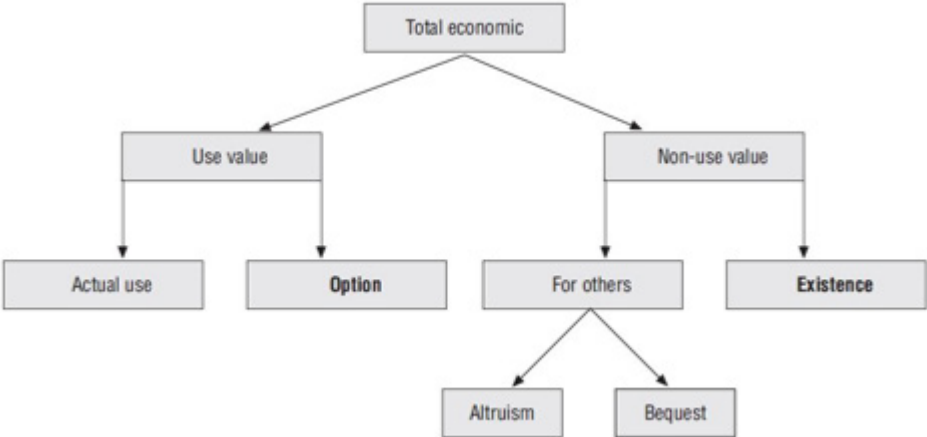
The problem with the first of these is the difficulty in defining "need", while the second suggests a necessary condition for sustaining utility, based on the assumption that there are limits beyond which human-made capital cannot substitute for natural capital in production processes. This is not inconsistent with a goal of non-declining utility, but the two approaches emphasise different things. The natural capital approach focuses more on the physical and ecological limits to sustainability (often referred to "environmental sustainability"). This second "scientific" approach has sometimes been compared with physical (thermodynamic) and ecological laws. The first law of thermodynamics essentially states that total matter and energy both remain constant in any isolated system; the first part of it is also called the law of matter conservation. The second law essentially means that the total amount of usefully concentrated matter and energy in an isolated system must decline.

The key thing to note with this concept of sustainability is it is not binary but a spectrum. The extreme view of weak sustainability is that there is no difference between capitals or the welfare generated from them – in practice this is not the case given the many difficulties involved in this. The same can be said for strong sustainability where natural capital is distinct from other capitals and cannot be substituted at all. The reality is that a combination of these two forms is required. However, an often ideal place to begin is one of strong sustainability and non-substitution with movement towards that of weak sustainability to find an optimal combination as there it is difficult to move the other way (Ekins, Deutsch, Folke & De Groot, 2003).

The Value of Natural Capital

The concept of TEV was defined in the 1980s in the emerging field of environmental economics, to give effect to the recognition that environmental resources have value beyond their current or potential tangible uses.

Figure 5 – TEV Framework



Source: OECD (2006).

This general framework has been recognised for the past 30 years, particularly in connection to non-market valuation techniques, but there are slight variations in interpretation and categorisation of the various value components.

Pearce et al. (1989) noted that “[w]hile the terminology is still not agreed, environmental economists have gone some considerable way towards a taxonomy of economic values as they relate to the natural environment”. Pagiola, von Ritter, and Bishop (2004) noted that “the breakdown and terminology vary slightly from analyst to analyst, but generally include (i) direct use value; (ii) indirect use value; (iii) option value; and (iv) non-use value. The first three are generally referred to as ‘use value’”.

There are numerous variants on the TEV diagram in the literature (see Appendix 1: TEV examples) and the OECD (2006) diagram is one of the simpler depictions. As such, it misses some useful distinctions.

Actual use is also known as **current use value** or **direct use value** and reflects mostly tangible values of uses made of an environmental resource.

- These are used directly by people for final consumption or inputs into production, including such things as harvesting of food products, timber, fuel or medicinal compounds, and non-consumptive uses such as recreational and cultural activities that use the environment *in situ* without extracting materials or organisms.

Indirect use value (sometimes called production support value) is an additional category that refers to benefits derived outside the ecosystem that creates them, such as carbon sequestration benefits for the global community, water filtration benefits for people downstream or the storm protection of mangroves that benefits coastal properties and infrastructure.

Option value is more accurately described as **future use value**, comprising:

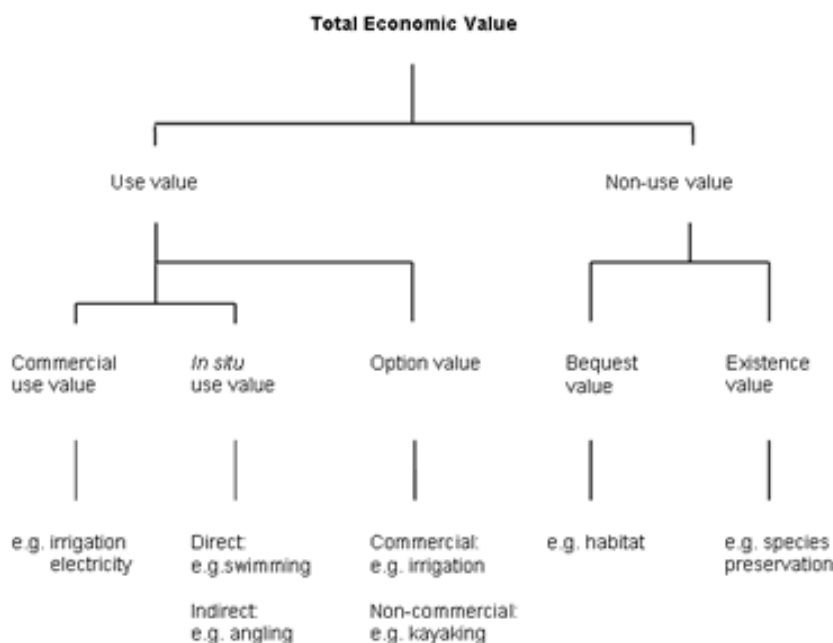
- **option value**, or the value of retaining something for future use, and
- **quasi-option value**, or the value of waiting for better information before committing to resource use which may be irreversible – which can also be construed as the potential value of as yet unknown attributes or uses of a resource that could be beneficial in future.

Value for others is an individual’s willingness to pay for the benefit of other people, both those alive today (altruism value) and those alive in future (bequest value).

Existence value is an individual’s willingness to pay for the benefit of other things, principally other species that are considered to have a right to continued existence, but sometimes more abstract notions (like environmental integrity).

One point worth noting is that the TEV framework includes the value of the ecosystem services that it provides people. For example, the TEV framework adopted by the Ministry for the Environment applied to water in the Waitaki Catchment, to aid consideration of major diversion includes the value of swimming, irrigation etc.

Figure 6 – TEV framework: Waitaki Catchment example



Source: Ministry for the Environment (2005)

Why Value Natural Capital?

Macro-level accounting

Much of the most obvious effort in natural capital is in the area of macro-level accounting. The focus of that effort has changed markedly from the early attempts at producing a green GDP or new economic welfare measures. Now natural capital is seen as part of the development of balance sheets to monitor the assets and liabilities faced by an economy, alongside similar efforts to view human capital as a function of educational and immigration policies, and social capital as a function of a wide range of legal and institutional policy settings. Natural capital is invoked for various purposes which affects the choice of technique:

- adjusting the national accounts that generate GDP to reflect depreciation of natural assets (eg, a net DP or Green GDP)
- providing a balance sheet of assets to be viewed alongside the GDP derived from the UN's System of National Accounts (SNA)
- providing for sustainable income by identifying a share of the proceeds of liquidating natural assets to invest in other assets yielding continuing income
- providing a clearer basis for monitoring changes in natural asset stocks than is provided by various ad hoc indicator sets, and
- in some (but by no means all) cases providing a basis for unitising natural assets and attaching an economic instrument to improve the choice of management options (eg, greenhouse gas emission inventories as a basis for emissions trading, fish quota as a basis for sustainable harvesting).

Various approaches

The current focus on practical natural capital accounting has been on natural assets that are most readily measured or estimated from existing data and converted to market values. This is now enshrined in the UN SEEA which provides a set of internationally agreed standards for preparing such accounts, covering both flow and transaction accounts and both physical measures and their valuation. The sectors and resources where natural capital accounting is being applied internationally include the following:

- non-renewable resources including oil and hydro-carbon stocks and other mineral resources, including precious metals, base metals and phosphate
- renewable resources (less frequently accounted for) including timber resources of forests; non-timber forest resources (eg, carbon sequestration), and
- more experimental natural capital stocks such as:
 - protected areas (a rough and ready indicator of the extent of biodiversity)
 - accessibility of natural resources for outdoor recreation and tourism
 - fisheries (may not be included in natural capital if implicitly and inextricably included in physical capital for the fishing industry)
 - water (difficult to quantify and often excluded altogether), and
 - soils (difficult to quantify and often omitted or partially included for carbon accounting).

The OECD states that the SEEA is the recommended approach for measuring natural capital and is essential for producing green growth indicators. In Australia, the Australian Bureau of Statistics (ABS) SEEA account for water provides the framework for managing scarce water resources. Statistics Netherlands' environmental accounts are used in the compilation of indicators for green growth. Eurostat has a long history of producing SEEA accounts, and recently used SEEA accounts to show that the EU induces emissions in other parts of the world through imports, but only for about the same amount as the EU exports. Eurostat's resource productivity measure is used as an indicator of sustainability as part of the Europe 2020 strategy which aims to shift Europe towards a resource-efficient, low-carbon economy to achieve sustainable growth. The UK's Office for National Statistics is aligning SEEA accounts to natural capital assessments.

Micro-level decision-making

In economic terms, value is a change in wellbeing, and valuation is the process of inferring value. The purpose of valuation is to establish the relative worth of things in satisfying human demands and needs. Valuation provides an indication of what can be obtained from resources when used in particular ways. When conflicts arise over the potential uses of a resource, the relative value of the resource used in different ways indicates which use would provide the largest return in benefits for people. Value is therefore a primary means of highlighting the trade-offs in resource use choices, and which choices to make to improve the efficiency of resource use.

For goods and services traded in markets the value is readily ascertained from observable market prices. But governments are largely in the business of addressing market failures, so for large areas of government activity there are no market prices with which to value government outputs. In fields such as conservation, defence, education, health and justice, the costs of providing services are easily identified, but the value obtained from them is unclear.

At the level of assessment of individual regulations or policies, approval of consents or appraisal of projects the question arises as to what weight to give to natural capital when considering its use or retention against developments that transform it in some way. Here the question is what will be gained or lost by the transformation, given that development gains are expected and readily quantified but the impacts of natural capital loss on the community are less obvious?

Various approaches

The ecosystem services approach provides a formal way of drawing links between ecological processes and functions and the services of value they provide to people, such as harvestable materials, carbon storage or flood risk reduction, and contributions to human wellbeing in the form of material income and reductions in safety risks. These have economic value in the form of costs avoided from averting property damage or productivity losses, or enhanced value reflecting people's preference not to be flooded or risk enhanced climate change in future. By identifying what these values are and where they accrue, the ecosystem services approach provides both a means of quantifying the values at risk and of identifying who gains or loses most, which is important in considering liabilities and who has greatest incentive to contribute towards providing ecosystem services.

Unless they are traded in markets, the value of ecosystem services has to be assessed in other ways. This may be by expert judgement, in which case values are implicit and may vary between individual decisions. It may be by judgement weighted by the number of people affected (eg, recreational uses of an open space) but this says little about the strength of preference for that particular use of a resource. Alternatively, they can be weighted by economic value, such as the number of recreational users multiplied by a unit value per use.

Or they may be assessed by other scoring criteria in a multi-criteria analysis in which economic considerations may be just one part.

Economists have devised non-market valuation techniques to provide economic values. Revealed preference techniques tend to be limited by the availability of observations of relevant behaviour; stated preference techniques are more flexible but subject to doubts about the reliability of answers to hypothetical questioning. Stated preference techniques have evolved from market research methods which have been shown to provide reliable results for market products, but reliability cannot be verified when applied to non-market natural capital that people are unfamiliar with paying for.

Questions also arise about whether the approach of non-market valuation, in trading off incremental gains and losses in environmental condition, is appropriate for all natural capital. For species that are critically endangered, there is a risk of incremental trade-offs pushing a resource beyond a critical threshold from which it is difficult and costly to recover. With their holistic approach to natural resources, Māori also may also view economic valuations as having limited scope in determining environmental values.

The ecosystem services approach has broad application to measuring the effects of natural resource domains that are affected by biological processes, including water quantity and quality, biodiversity, soil retention, land cover and associated emission and carbon storage characteristics, wild stocks like fish and insect pollination. Non-market valuation also has potentially wide application, but it is dependent on accurate depiction of the environmental effects being valued and the existence of credible trade-offs.

A common thread to all natural capital approaches is the importance of reliable physical inventory or stock of the resources being assessed. Scarcity matters, raising the probability of loss and the value in averting loss. Stocks are fundamental to accounts and they are also important for monitoring the condition of ecosystems, in both quantitative and qualitative terms. Stock issues such as scarcity of a resource or accessibility to substitutes are also influential on economic value, but are less obviously given prominence in non-market valuation studies.

Putting a Dollar or Number on Natural Capital

It is important to note that valuation is unavoidable. We already value natural capital and the ecosystems services every time a decision is made involving trade-offs concerning them. The problem is that the valuation is implicit in the decision, hidden from view and usually based on a single person's values. Improved transparency about the valuation of natural capital and ecosystem services (while recognising the uncertainties and limitations) can only help to make more informed decisions (Costanza et al. 1997).

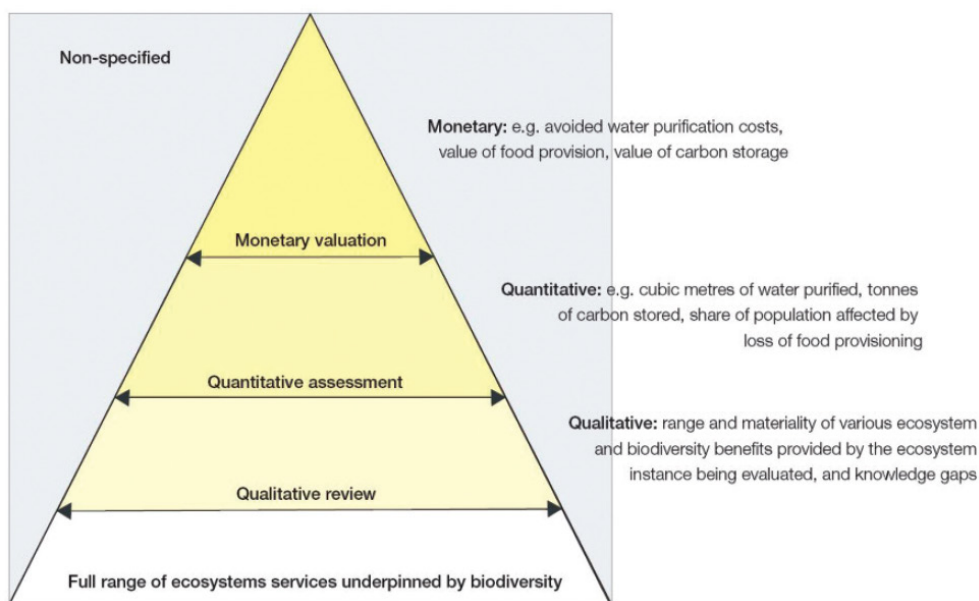
To put an economic value on changes to natural capital and ecosystem services, we first need to understand what those changes are. In examining choices over the use (or non-use of) of natural or environmental resources it is useful to apply a three-stage procedure:

- identifying effects, whether they are positive or negative to people's wellbeing, and when they are likely to occur (qualitative)
- quantifying effects to the extent possible (quantitative), and

- converting effects to a common currency for comparison through monetary valuations made time-consistent through discounting (monetary)

Qualitative analysis generally focuses on non-numerical information, quantitative analysis focuses on numerical data and monetary analysis focuses on translating these data into a particular currency. All three types of analysis are useful, but they provide different levels of information to a decision maker. A pragmatic approach to valuation can be summed up as follows: “always identify impacts qualitatively, then quantify what you can, then monetise (where possible)” (TEEB 2009).

Figure 7 – Pragmatic approach to valuation



Source: Ten Brink (2008)

The economic value of natural capital is most usefully expressed in monetary terms consistent with other assets and inputs in production activities. Putting a price on nature is highly contentious but shying away from it misses the point of economic valuation. This arises because there are not infinite resources to devote to protecting nature, so hard choices need to be made about using or conserving natural resources. Monetisation is not privatisation. Commensurate values for all potential uses or non-uses are useful for informing those choices. Some bits of nature cost more than others to protect, and some are valued more highly than others because they yield more benefits. Economic valuation informs choices, but as a resource’s price reflects the relationship between its supply and demand for what it provides, value also depends on accurate measures of the physical extent and condition of natural resources. Such definitions are still relatively vague, but they give a flavour of what measures of natural capital need to capture. These include:

- value is an encapsulation of a stream of services expected from natural resources over future years
- such services are of benefit to, and valued by, people, and
- natural capital value needs to reflect the scarcity or abundance of the services derived from it relative to their demand.

Valuing Natural Capital Methods

Some elements of natural capital produce services with market values but some do not, raising the question of how to assign values to them. This is the role for which non-market valuation techniques have been developed, but there is a wider range of valuation options.

The economic values are based on observed willingness to pay for the market or non-market goods and services from the natural resource. Where a value is required for a natural resource with non-market attributes, a range of methods could potentially be employed. These include:

- valuing solely at the value of marketable output from the resource, for instance the sales value of timber or non-timber produce from a forest – a partial value of TEV as the non-market values are omitted
- estimating the economic impacts associated with the resource, for instance the value of timber plus the value for tourist accommodation and other services derived from recreational visitors to the forest – this is still incomplete but captures part of the value associated with non-market use, and it is aligned to the national accounting framework, allowing value added and incomes to local employees and business owners to be inferred from the output values
- estimating the economic rents from the resource, which is the surplus value attributable to the natural resource after the full costs have been deducted from all other inputs in producing those outputs (such as timber) – this applies solely to the revenues from marketable goods, and if it is not calculated, the rent usually accrues as a producer surplus to the operation that creates the revenue stream, and
- estimating the consumer surplus associated with the non-market use or non-use of the resource, that is the value in the resource simply being there, retained for future use or just for its own sake.

There is a long history of economic non-market valuation techniques being developed to assist in weighing up effects on the natural environment, including intangible aspects that affect wellbeing (such as option values and existence values). A suite of techniques has been developed to infer how people value outcomes that are not amenable to market trading. These include (see Appendix 2: Valuation Techniques for more information):

- **market-based measures**, such as inferring the value of a natural area's contribution to water purification from the cost of alternative ways of obtaining water of equivalent quality
- **cost-based measures**, such as valuing the loss of natural habitat at the cost of replacing it elsewhere, on the assumption that the total stock of that habitat should not be reduced, and
- **production-based measures**, such as inferring the contribution of water to agricultural production by analysing the value of outputs from production systems with and without availability of water.

The most sophisticated of these techniques calculates a consumer surplus value that is incompatible with natural capital accounting (or at least cannot be incorporated in national accounts unless the consumer surplus values for all other things are explicitly taken into account). So these non-market valuation techniques have limited relevance to high level natural capital accounting. They can still be used in project appraisal and informing lower-level decisions about individual site use.

Natural Capital in New Zealand

In order to understand the overall state and value of natural capital in New Zealand, a framework will have to be created to define the appropriate method of valuation for all aspects of natural resources.

The following sections will present analysis based on the currently available data, the first looking at putting a dollar value on New Zealand natural capital, and the second supplementing the dollar value approach with available indicators.

Dollar value – national accounts

Natural capital accounts offer a consistent way of looking at the significance of nature, beyond simply a compilation of disparate facts and figures. They can help identify drivers of ecosystem change within the wider economy and society and they can help understand whether New Zealand stocks of natural capital are being used sustainably. By linking in to the national accounts they can also provide comprehensive, integrated and consistent data sets, supporting the robust integration of economic environmental information.

The development of monetary accounts has a particularly important role to play in integrating environmental and economic information. Specifically, estimates of the value of natural capital assets can contribute to provide a more comprehensive picture of the nation's balance sheet.

Over the period 2001-05, Stats NZ began to establish 'natural resource accounts' based on the on the SEEA framework (Stats NZ, 2002). The focus was on establishing stock and flow accounts, measured both in monetary and physical terms. Stats NZ released environmental accounts for:

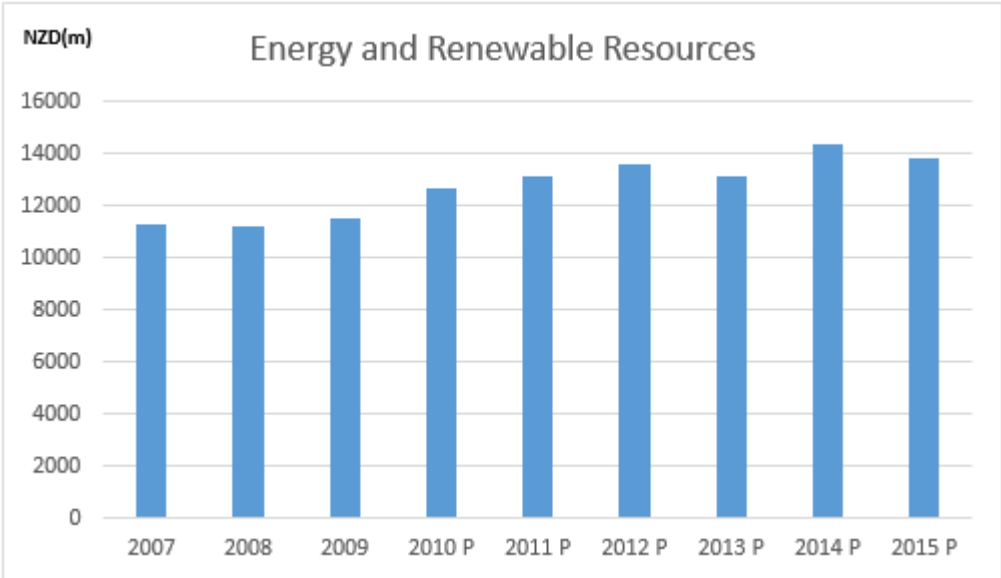
- energy and emissions (the latest release covered the period 1997-2003)
- environmental protection spending (2001-03)
- fish stocks (1996-2016)
- forestry (1995-2016)
- marine economy (1997-2002)
- minerals (1994-2000), and
- water stocks (1995-2014).

The accounts do not cover the full range of potential accounts, and data gaps exists in all of these. Most accounts provide estimates at the national level, with minimal sectoral or regional breakdown.

Energy and emission

These accounts provide information about the asset values of renewable energy resources in New Zealand. The information recorded also details a breakdown of national and industry-level information on energy demand, economic activity, and gas emissions.

Figure 8 – Energy and renewable resources



The impact of humans on the environment is a function of total population, per capita consumption and waste generations, the type of technologies used and the finite capacity of the environment to absorb waste. Globally, growth in human population and income is seen as a major driver of environmental deterioration.

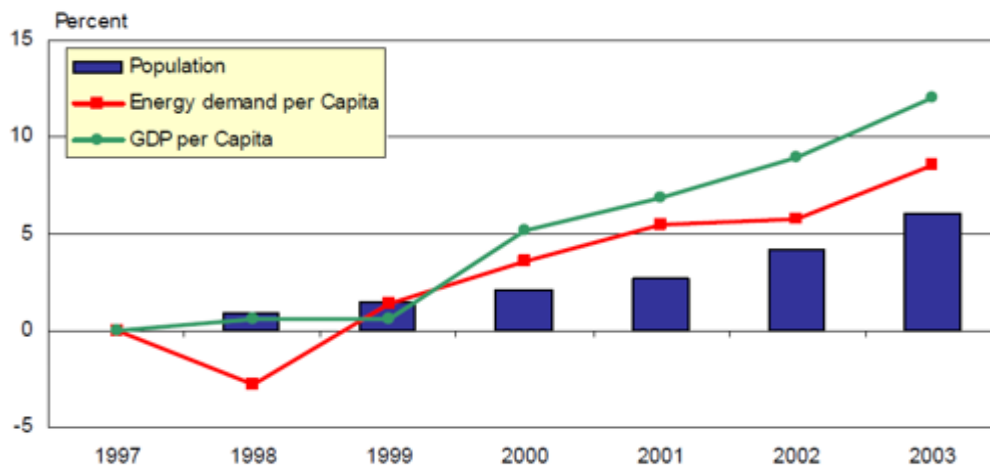
The energy and emissions data captured to date attempts to show how New Zealand’s society and economy are impacting the environment through final consumer energy demand requirements and gas emissions from the use of energy commodities.

Energy demand in this report is in terms of total final consumer demand which is the demand for energy products (coal, oil, gas, electricity, etc) by New Zealand’s households and intermediate consumers (government and businesses) and includes:

- non-energy use of energy products (such as gas for methanol and urea production)
- international transport (undertaken by business units resident in New Zealand), and
- refinery intermediates and residues.

During the period 1997 to 2003, New Zealand’s economy has continued to grow with GDP per capita increasing by over 12%. During the same period, New Zealand’s population has increased by around 6%. As both the economy and population have continued to grow so has the demand for energy, especially in the form of fossil fuels. The figure below shows the energy, economy and population situation for New Zealand for the period 1997 to 2003.

Figure 9 – Energy demand per capita



Source: Stats NZ (2015)

The data have the following limitations:

- The data only focus on use value.
- Interpretations need to reflect that the data only covers final consumer energy demand.

Environmental protection expenditure

Environmental protection expenditure (EPE) is an internationally recognised term used to describe all goods and services aimed at protecting the environment and encouraging the sustainable use of the earth's natural resources.

The calculated value of New Zealand's public sector EPE (current and capital) was \$1,165.3 million for the year ended June 2001, \$1,249.6 million for the year ended June 2002 and \$1,267.5 million for the year ended June 2003.

New Zealand's public sector spent \$767.9 million on natural resource management in the year ended June 2001, \$782.8 million in the year ended June 2002 and \$764.9 million in the year ended June 2003.

Central government spending on EPE grew at a faster rate than local government expenditure. This was owing to increased spending by the Department of Conservation on the Department's recreational facilities. This increase in spending started in the year ended June 2003. However, local government EPE is still three times larger than central government EPE.

Local government EPE grew by 6.9% in the year ended June 2002, and by 0.8% in the year ended June 2003. The year ended June 2002 included spending on large capital projects including the Hutt City Council Seaview waste water treatment plant.

If the EPE data are complete and up to date they can provide the following benefits:

- They allow an estimate of the contribution of the "environment industry" towards GDP, and can be presented as satellite accounts to supplement the national accounts.
- They assist the analysis of the impact of economic and social policies on the environment.

- They provide an indication of the level of demand for goods and services provided by the “environmental management” industry, as well as how much is spent on environmental protection by industrial and institutional sector, and within the environmental domain.
- They identify the sectors that are financing EPE.

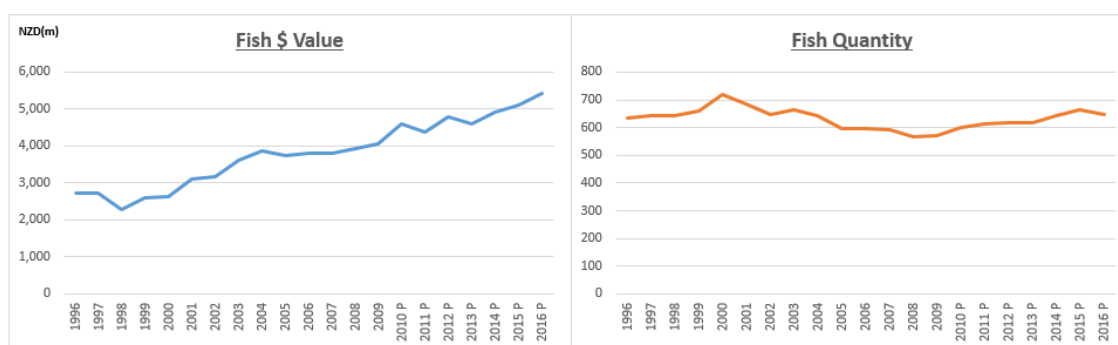
The data have the following limitations:

- Data coverage is very limited as only three years of data are available
- The data currently excludes the household and private sector as on-going reliable data are not available.

Fish stocks

This approach takes the total allowable commercial catch (TACC) and compares it with the total asset value of fish species in New Zealand per year. Taking this approach allows analysis of how the value of the asset has changed between 1996 and 2016 but also what species of stock changes including depletion are driving this change.

Figure 10 – Fish dollar value and quantity



The monetary value (trend) has been increasing since 1989, as opposed to the TACC which has been fairly consistent or marginally declining. This implies that the prices of the various fish species have been increasing steadily over the past 10 years.

In 2015, the total contribution (direct, indirect and induced) to GDP was \$776.4 million, or 3% of GDP.

The available data are insufficient to determine if the implementation of TACC has had the desired impact of growing the fish stocks of New Zealand.

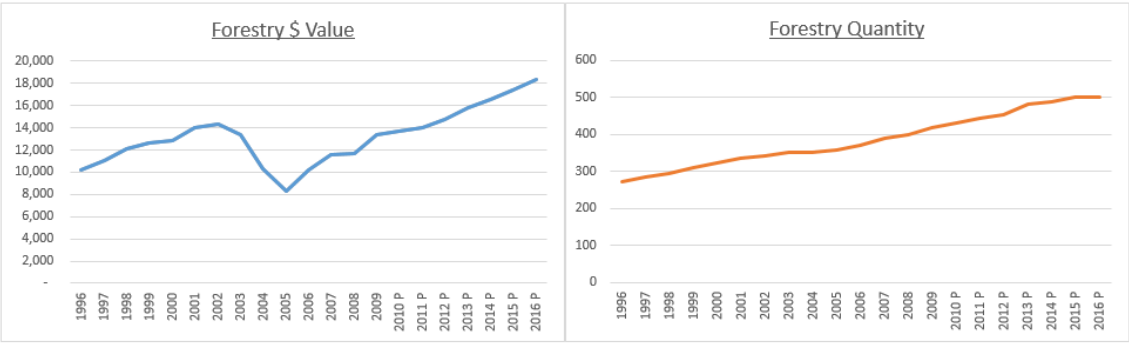
The data have the following limitations:

- They only take into consideration the use value of fish stock, and excludes the non-use value
- The data coverage is limited as the total number of stocks is not considered, nor are the sizes of the fish considered
- The “use” data are also restricted as they only account for commercial catches and ignore other activity such as customary and recreational fishing.

Forestry

The accounts do not cover the full range of potential accounts, and data gaps exist in all of these. Most accounts provide estimates at the national level, with minimal sectoral or regional breakdown.

Figure 11 – Forestry dollar value and quantity



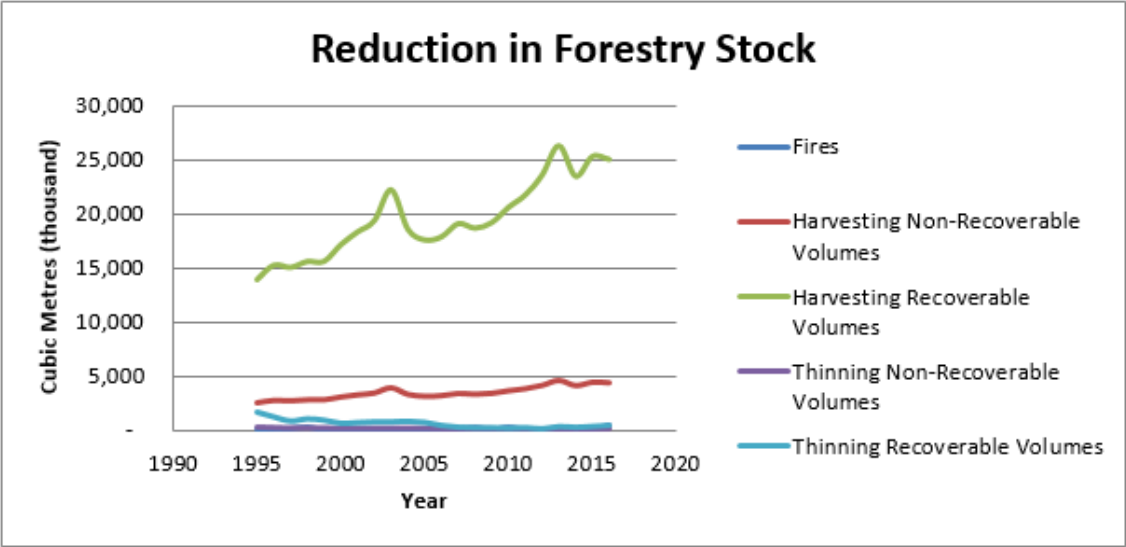
Forestry is a significant contributor to GDP in New Zealand. Exports from forestry are expected to reach \$4.8 billion in 2017. Given forestry’s earning potential the sustainability of this resource is an important part of the New Zealand natural capital story.

Overall, the trend in the stock is that the physical forestry asset is increasing slightly (not clearly observable, owing to the scale of the graph) and this is likely a combination of an increased volume – as total standing timber is steadily increasing – but also an increased monetary yield (which could be owing to the quality of timber being harvested; however, these data are not available)

A notable trend is the decline in 2005. However, looking at the harvesting non-recoverable values for 2004 it suggests the decrease in monetary stock is explained by an excess supply in the previous year decreasing the price.

Additions to the forestry stock are recorded as natural growth, new planting and restocking and reductions to the total forestry stock are categorised by the impacts of fires, harvesting, and thinning volumes (both in terms of recoverable and non-recoverable). Interestingly both of these components represent a very small component of over standing timber and therefore the existence value for the stock may be quite significantly undervalued currently.

Figure 12 – Reduction in forestry stock



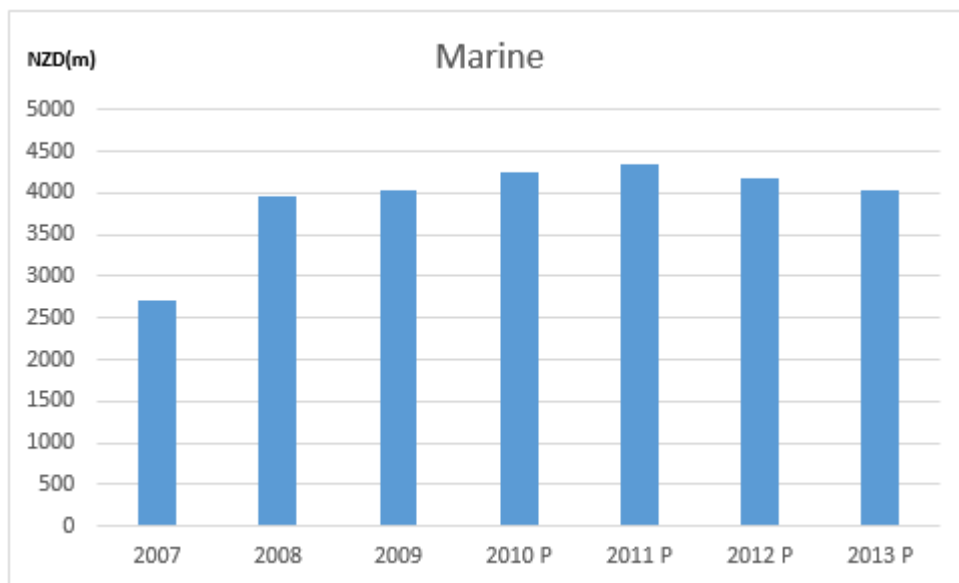
Limitations of these data include:

- Only use value is recorded.
- Data coverage is limited as additional information around the types of stock (trees), the quality of the timber and regional coverage would be of use.

Marine economy

The accounts provide information about the economic activities that took place in, or used, the marine environment, or that produced goods and services necessary for those activities, and made a direct contribution to the national economy from 2007 to 2013.

Figure 13 – Marine



The marine economy contributed \$4 billion to New Zealand's economy (1.9% of total GDP).

Offshore minerals (mainly oil and gas) were the largest contributor to the marine economy, at 48% (\$2 billion).

Shipping, and fisheries and aquaculture contributed 24% and 22% respectively.

There were 102,400 filled jobs in New Zealand's marine economy.

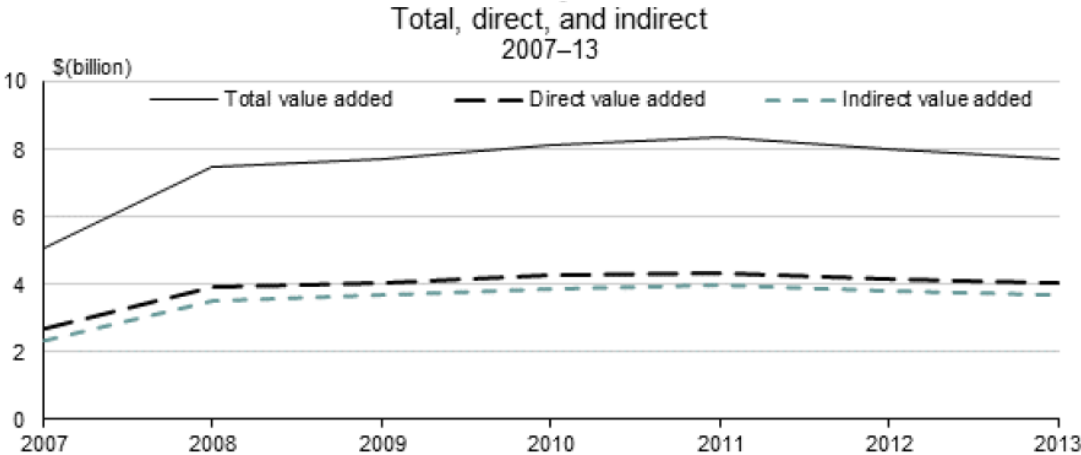
Of these filled jobs, 47% were in shipping and 46% in fisheries and aquaculture.

Total marine economy value added, including indirect effects, was estimated at \$7.7 billion (3.5% of GDP). The indirect component accounted for \$3.7 billion of this value, or 47.7% of total marine economy value added.

The strong growth in the marine economy between 2007 and 2008 was attributed to increased value added from offshore minerals.

The graph below shows the marine economy value added for the period 2007 to 2013.

Figure 14 – Marine economy value added



Limitations of these data include:

- Only use value is recorded.
- Data coverage excludes research and education, government and defence, marine manufacturing and marine construction.
- It also excludes cultivated aquatic resources (differentiating between stock for harvest and for breeding) and natural aquatic resources.

Minerals

In 2000 the total asset value of New Zealand’s economically utilised mineral resources (excluding coal and petroleum) was \$223 million.

Of this, \$130 million was non-metallic minerals and \$93 million was metallic minerals.

In 2000, aggregate had the highest asset value of all utilised minerals, valued at \$105 million.

Gold recorded the second highest asset value of all minerals at \$77 million, the highest for metallic minerals.

Coal stocks valued at \$398 million, oil stocks at \$793 million, gas stocks at \$2,770 million, and renewable hydro-electrical energy was valued at \$3,670 million.

Physical stocks of aggregate and limestone in New Zealand cannot be measured exactly but are known to be very large.

Of metallic minerals only gold, silver and ironsand concentrate are currently economically utilised at significant rates. However, physical stocks of other metallic minerals exist and have the potential to be economically utilised in the future.

Limitations of these data include:

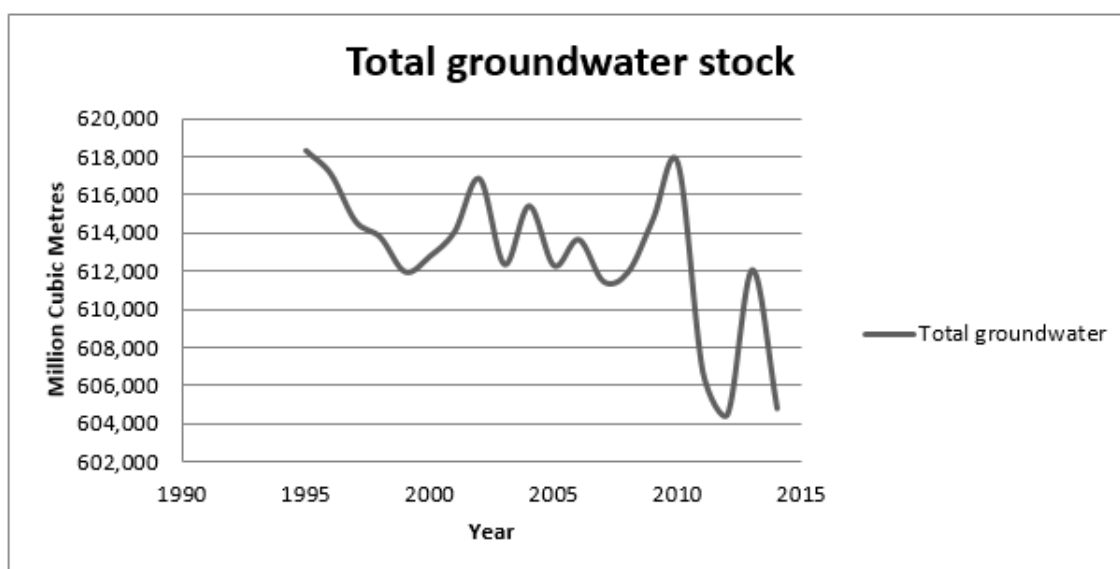
- Only use value is recorded.
- Data coverage is limited as only 4 years of data is available.
- Not all minerals are covered and quality measures of minerals are missing.

Water stocks

This dataset provides the total ground water stock and the inflows and outflows by activity type where the data are available. This dataset does not provide a monetary valuation of water use.

This graph of total groundwater stock exhibits a declining overall trend which suggests the use of groundwater stocks is greater than the rate of replacement.

Figure 15 – Total groundwater stock



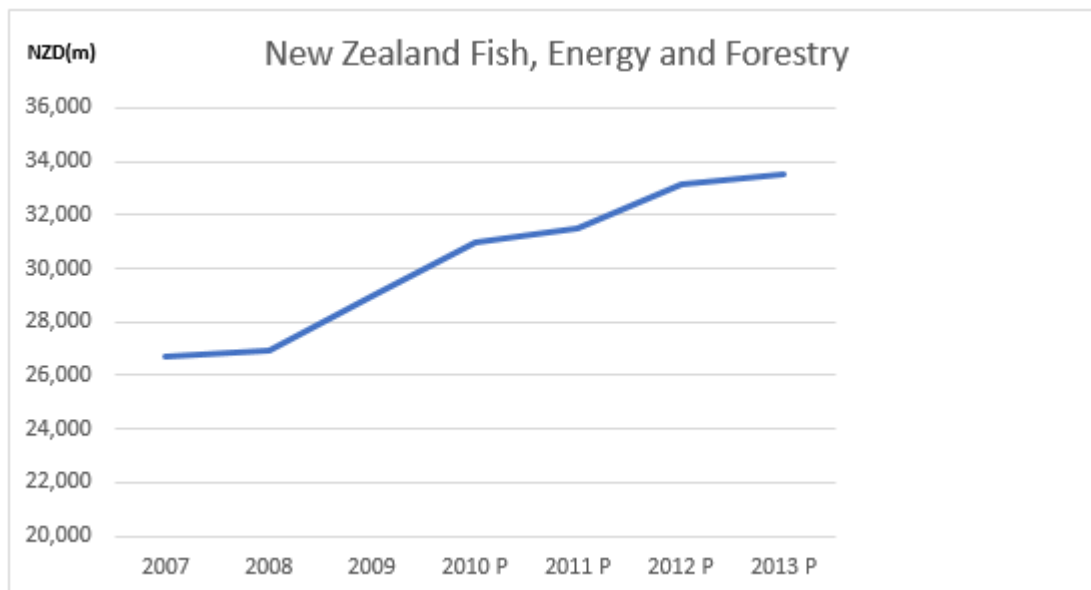
Limitations of these data include:

- Only use value is recorded
- Data coverage is limited and the following gaps have been identified:
 - the monetary value of water stocks
 - quality measures of water stocks, and
 - accounts for rivers and streams.

An aggregate view of SEEA data

One of the benefits of the SEEA environmental accounts is the monetised value of natural resources. This lends itself to the calculation of a total value of natural capital. However, it should be noted that the current national accounts as maintained by Stats NZ do not cover all components of natural capital (use and non-use) and the monetary values in this sections should only be considered as an indication of the trend of natural capital where there are overlaps in terms of data availability.

Figure 16 – New Zealand fish, energy and forestry



The graph suggests that for the sectors covered by the New Zealand environmental accounts (fish, energy and forestry), the general trend is positive and the monetised value of these environmental assets is increasing.

It should be noted that the data are incomplete as they do not provide a full picture of the environmental accounts represented and several natural resource sectors are omitted, including but not limited to:

- atmosphere and climate
- biodiversity
- soil, and
- threatened species.

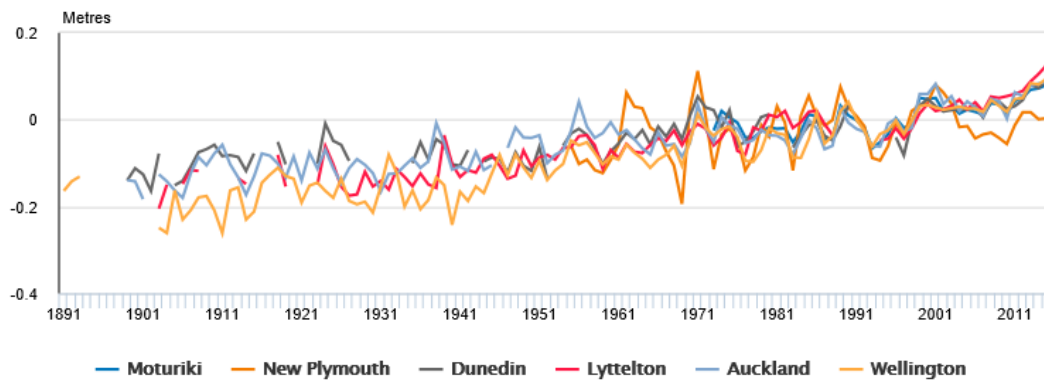
Environmental Indicators

The following section illustrates the natural resource indicators published by the Ministry for the Environment and Stats NZ, which can be used to fill the gaps identified above and extend the valuation framework for the natural capital in New Zealand.

Marine

Most sites experienced higher sea levels in the last 20 years. Available tide gauge data showed rising linear trends in all long-term monitored sites throughout the period for which data are available, with the trend most significant in the Wellington site.

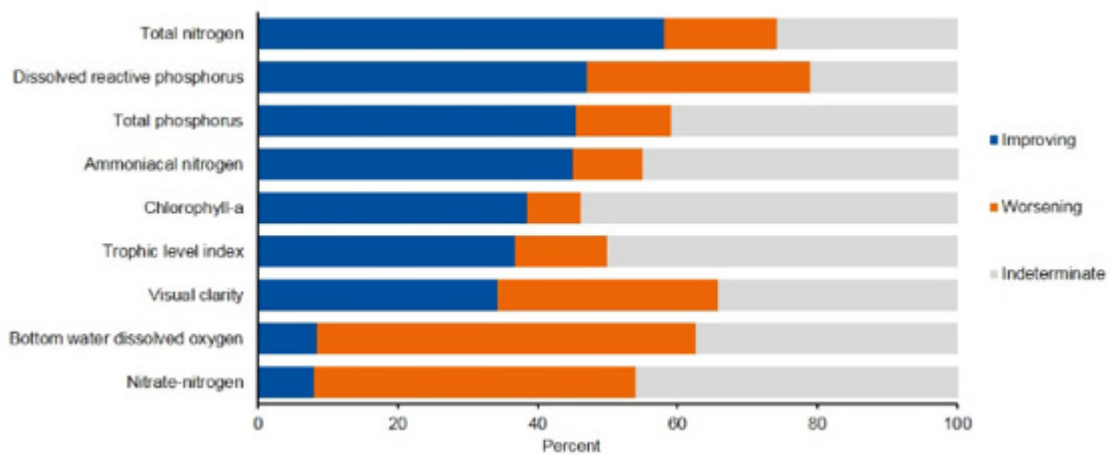
Figure 17 – Change in annual mean sea level by monitoring site, 1891-2015 (relative to 1986-2005 baseline average)



Water

The international measurement of the lake water quality includes monitoring of the nine characteristics listed below. The figure below shows a declining trend across all characteristics for the 10 year period ending 2013.

Figure 18 – Lake water quality measures, 2004-13

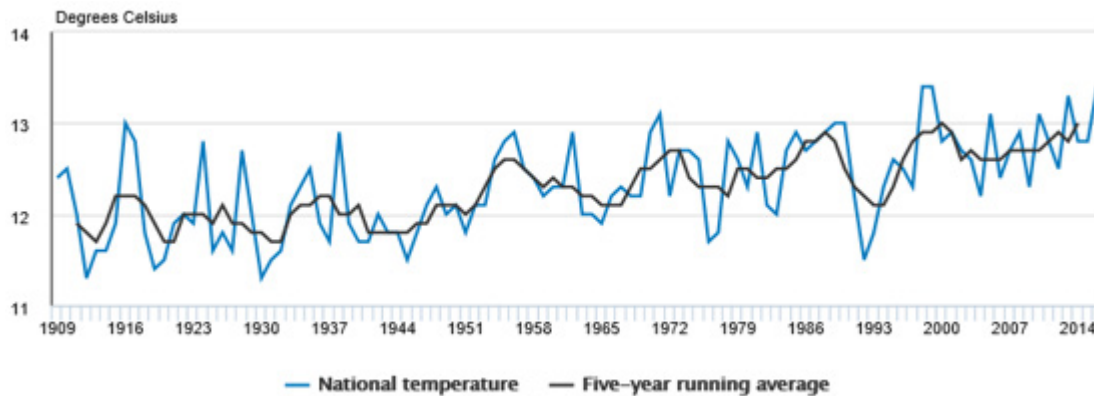


Atmosphere and climate

From 1909, New Zealand's warmest year was 2016. Over this period, the annual average temperature was 12.3 degrees Celsius.

The graph below shows an upward trend in the average national temperature over the past 50 years.

Figure 19 – Annual average temperature, 1909-2016

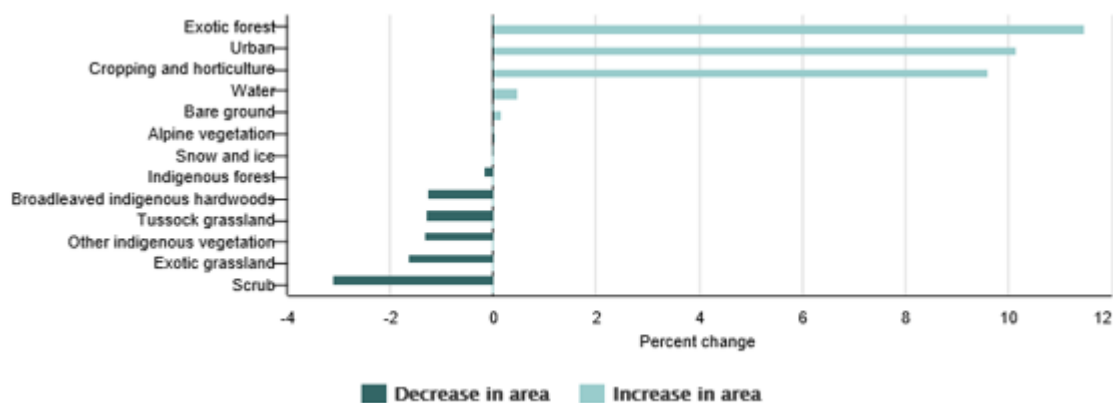


Land

As a national indicator, land cover is considered a direct measure of “Vegetation and other land cover” topic.

The graph below shows the decline of the indigenous species, whilst the cover due to deliberate human intervention has increased significantly.

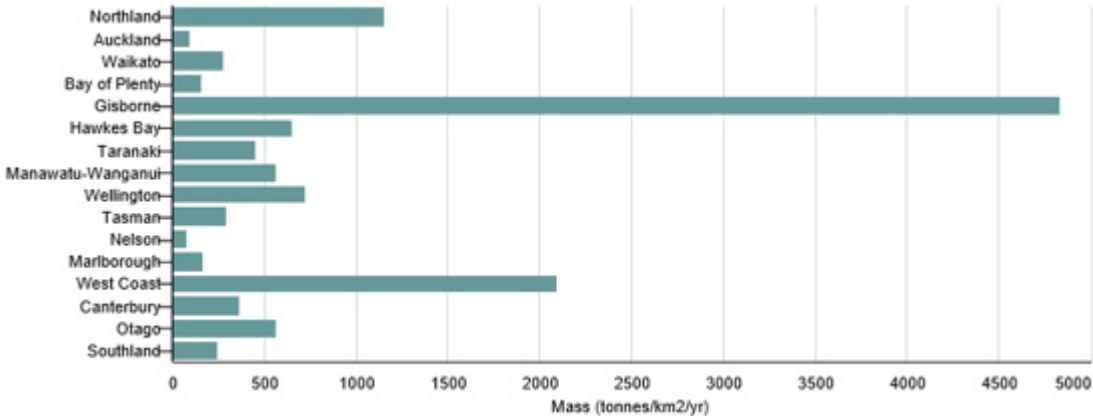
Figure 20 – Percent change in area of land cover classes, 1996-2012



In 2012, it was estimated that 192 million tonnes of eroded soil entered New Zealand’s river each year.

Gisborne, West Coast, and Northland regions each had estimated average soil erosion rates of more than 1,000 tonnes per square kilometre a year.

Figure 21 – Estimated average volume of soil erosion by region, 2012



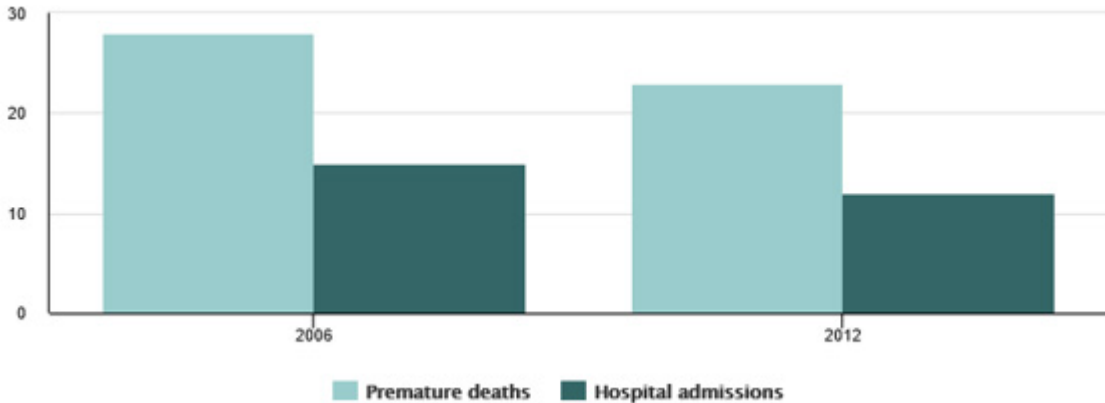
Air

Particulate matter 10 micrometres or less in diameter (PM₁₀) in the air comprises solid particles and liquid droplets from both natural and human-made sources. It is of particular concern because high concentrations can damage health, with associated effects ranging from respiratory irritation to cancer.

This indicator considers PM₁₀ from human-made sources, such as burning wood or coal for home heating or road motor vehicle emissions.

The figure below shows a decline in hospital admissions and premature deaths and this is consistent with a decrease in households using wood or coal for heating.

Figure 22 – Estimated health effects from exposure to human-made PM10



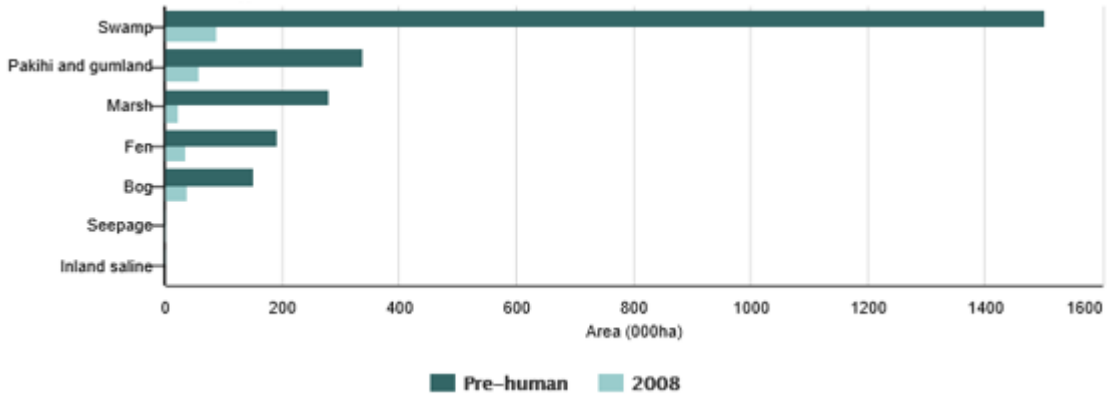
Biodiversity

Wetlands support unique biodiversity and provide important services. They clean water of excess nutrients and sediment, help absorb floodwaters and act as carbon sinks.

Draining wetlands for agricultural and urban development over the past 150 years has significantly reduced their extent, leading to a loss of biodiversity and natural function.

In 2008, wetlands only covered 0.9% of New Zealand’s land cover, compared to an estimated 9.2% of land cover in pre-human time.

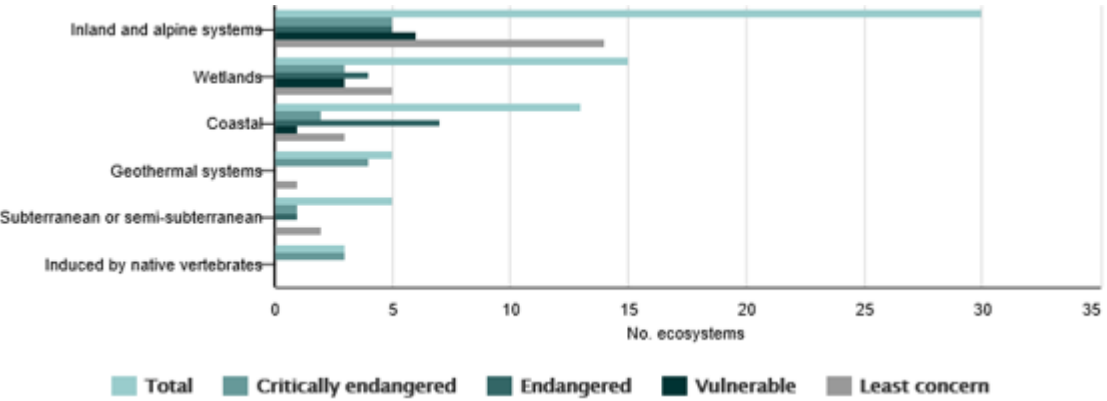
Figure 23 – Change in wetland area, prehuman and 2008



In 2014, New Zealand had 71 identified rare ecosystems, with 45 of them threatened with extinction.

Inland and alpine systems had the largest number of rare ecosystems (30), with just over half (16) threatened.

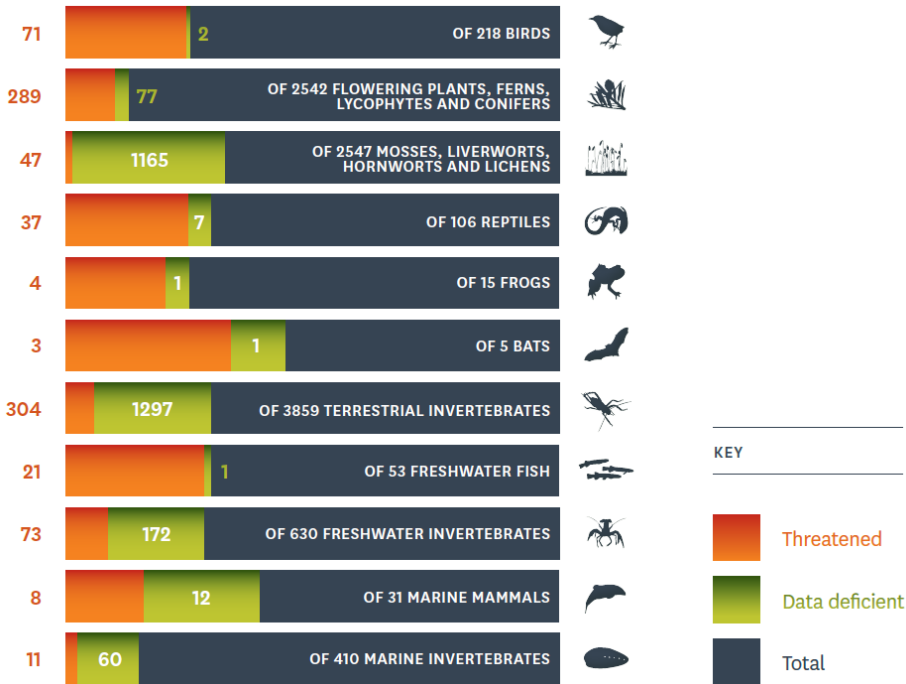
Figure 24 – Threat status of rare ecosystems by class, 2014



Around 81% of invertebrates, 70% of birds, 84% of freshwater fish, and 80% of trees, ferns and flowering plants are unique to New Zealand. This biodiversity defines New Zealand and adds immeasurable value to our culture, identity and wild places.

Presently, more than 3000 of our native species are classified as “threatened” (800) and facing extinction, or “at-risk” (remaining 2200) and could see their populations decline through some slight change in conditions.

Figure 25 – Number of threatened species by broad taxonomic group



Source: Department of Conservation (2017)

Aggregated environmental indicator view

Overall, the environmental indicators show a downward trend and suggest that the overall state of the environment is declining.

Summary view of New Zealand natural capital

New Zealand’s natural environment provides tremendous benefits on several levels. Easy access to pristine wilderness and good air quality heighten quality of life for all, while the spectacular landscapes attract millions of visitors every year.

Apart from the economic benefits of tourism, the natural environment provides the basis for the country’s large exports of dairy, meat, wool, fruit, vegetables, fish and wood.

New Zealand’s growth model is approaching its environmental limits. Greenhouse gas (GHG) emissions are increasing.

Pollution of freshwater is spreading over a wider area.

The country’s biodiversity is under threat.

Although some conclusions can be drawn from the analysis completed to date, the exercise has highlighted the gaps and limitations of both approaches and further strengthens the view that significant work will be required to define the appropriate measures for each type of natural resource and ensure that the required data for each measure are accurate and readily available.

Comparison with other countries: United Kingdom (UK)

SEEA approach to Natural Capital

In 2015, the UK Office for National Statistics (ONS) published a roadmap, *Accounting for the value of nature in the UK*, which set out a strategy to incorporate natural capital into the UK environmental accounts by 2020.

As part of the roadmap, ONS outlined a plan to develop natural capital estimates within the framework of comprehensive wealth accounts to provide an overview of the value of natural capital within the UK.

In June 2013, ONS published a paper, *Towards wealth accounting – Natural capital within comprehensive wealth*, to share its plan for developing UK natural capital estimates.

May 2014, ONS published its first attempt of estimating UK natural capital estimates using wealth accounting approaches.

Following further development, these estimates will be incorporated into the UK environmental accounts – a “satellite account” (accounts that provide information for the wider impact analysis of the economic changes) to the main national accounts

The prioritisation of the UK environmental accounts can be broadly described as:

- the establishment of ‘base’ environmental accounts per sector
- the establishment of Aggregate UK Natural Capital Estimates (so-called ‘Top down’ accounts)
- enabling/cross cutting accounts, and
- habitat-based accounts.

In comparison, the current status of the New Zealand environmental accounts can be compared to the “base” environmental accounts per sector, although the coverage of the current accounts are not yet sufficient to provide a realistic estimate of the natural capital

The investment the UK is making in the creation and maintenance of environmental accounts and the associated satellite accounts, can serve as a guide for the investment required to bring the New Zealand environmental accounts to a level where estimates for natural capital will be realistic and the impact on the economy measurable.

Ecosystem assessment approach to natural capital

The 2011 UK National Ecosystems Assessment (UK NEA) concluded that the natural world and its ecosystems are important to our wellbeing and economic prosperity, yet they are consistently undervalued in conventional economic analysis and decision-making.

The UK National Ecosystem Assessment Follow-on (UK NEAFO) programme was established to provide new information and tools to help decision-makers across all sectors understand the wider value of ecosystems and the services they offer.

The framework developed by UK NEAFO includes:

- an overarching Ecosystem Services Conception Framework for the management of ecosystem services which reflects a deepened understanding of the roles of governance and institutions in the decision-making process, and the importance of built, human and social capital in transforming natural capital and the flow of ecosystem services into goods and benefits for people
- adaptive management principals, which offer flexible responses to inform policy- and decision-making as knowledge grows
- a Decision Support System (DSS) toolbox which offers a set of tools by which decisions regarding ecosystems and their services may be supported, and
- a balance sheet approach for interrogating and presenting evidence from appraisals that can be adapted according to the complexity and importance of the issue under consideration.

This framework provides policy-makers and practitioners with advice on which methodologies and tools are best for a given situation, how they should be used and in which combination.

Genuine Savings as an Indicator of Sustainable Development

The material below is drawn from Oxley, Qasim & McLaughlin (2017) *Geniune Savings as a Test of New Zealand Weak Sustainability*. Having now explored some of the data on natural capital in New Zealand, a key question to ask is whether New Zealand is on sustainable development path. Genuine Savings (GS) – also referred to as Adjusted Net Savings (ANS), Comprehensive Investment and Inclusive Investment – has become an important indicator of sustainable development over the long-run (Arrow, Dasgupta, Goulder, Mumford & Oleson, 2012, Ducoing Ruiz, Blum & McLaughlin, 2016, Greasley et al., 2014, Hamilton & Clemens, 1999, Pezzey, 2004).

GS was first proposed by Pearce and Atkinson (1993) as an indicator of weak sustainability, based on the Hartwick Rule (Hartwick, 1977, 1990) according to which income from the exploitation of non-renewable resources should be reinvested in renewable resources in order to maintain total wealth and to achieve non-declining wellbeing over time. Following this framework, Pearce and Atkinson (Pearce & Atkinson, 1993, Pearce, Markandya & Barbier, 1989) elaborated on the approach to suggest that an economy that saves more than the combined depreciation of its stocks of natural capital and produced capital will be (weakly) sustainable. Whenever GS takes negative values, it indicates that the economy is on an unsustainable development path.

According to (Hamilton & Atkinson, 2006), if the total wealth (sum of all types of capital stocks ie, human capital, produced capital and natural) is related to social welfare, whatever sustainability definition is used, it necessarily involves the creation and maintenance of total wealth. In other words, non-declining per capita total wealth has to be maintained intergenerationally to realise sustainability (Dasgupta & Mäler, 2001).

Hartwick (1977) developed a general rule that the rents produced from the depletion of the non-renewable resource should be reinvested in the produced capital. This could be considered as a general rule of weak sustainability where the rate of change of net capital investment, which includes gross investment in all types of capital which is measurable and

subtractable from depreciation or consumption, is not allowed to become negative (Hamilton, 1994). Assuming substitutability between different types of capital stocks (ie, produced, natural and human capital), GS measures year-on-year changes in total capital. A country is said to be sustainable if it maintains or increases the overall stocks of capital (Pearce & Atkinson, 1993).

Hartwick's (1977) and Solow's (1974) models impute renewable and non-renewable resources within a Cobb-Douglas production function model which is characterised by a unitary and constant elasticity of substitution between all factors of production. In other words, it assumes that natural capital and produced capital are similar and substitutable. To validate this assumption, either of the following must hold: i) natural resources are abundant; ii) or the elasticity of substitution between natural capital and produced capital is equal to or greater than unity; iii) technological advancement can boost productivity of natural capital at a higher rate than its depletion (Dietz & Neumayer, 2007). In order to measure weak sustainability, we need to associate economic values to the reduction in the quantity of natural capital and to environmental degradation (ie, the economic cost of damage to the quality of natural capital). This will enable planners to correctly understand if the natural capital losses are being compensated equivalently or not. Commonly used measures of weak sustainability are: environmentally-adjusted net product; GS; measures of resource depletion; measures of environmental degradation; the index of sustainable economic welfare etc. (Asheim, 1994; Dietz & Neumayer, 2007; Pearce & Atkinson, 1993, Quiggin, 1997; Romero & Linares, 2014). Among these indicators, GS is a widely used indicator of sustainable development and long-term wellbeing. The World Bank has been publishing measures of GS for a panel of countries since 1970.

Empirical testing of genuine savings

Having discussed the key literature on the long-term relationship between GS and future wellbeing above, there is still relatively inadequate evidence on their empirical relationship. Oxley, Qasim and McLaughlin (2017), uses the GS and future wellbeing framework proposed by Ferreira, Hamilton and Vincent (2008), and apply it to New Zealand data.

They extend the World Bank work in a number of important ways. Firstly, they use data from multiple resources in New Zealand, over an extended period of time (1950 – 2015), to more closely approximate or proxy the definitions of the variables in the theoretical model. Secondly, they examined the effect of time as an uncontrolled capital stock through exogenous technological progress (using a measure of total factor productivity – TFP, which expands the production possibilities of the economy) (Pezzey, Hanley, Turner, & Tinch, 2006). One important contribution here is that they matched time horizons applied to discount TFP series with that of the dependent variable discussed in detail in the data section. In previous studies, this has been kept constant, for example, Greasley et al. (2014b) and Blum, McLaughlin, & Hanley (2013). Or it has been set at 20 years or 30 years in Hanley et al. (2016). Thirdly, they captured changes in human capital through investments in education. According to Hamilton & Atkins (2006), the process of development can be characterised as economies converting their natural capital into the other forms of capital eg, human capital, produced capital. Similarly, the importance of human capital for long-term development, is also acknowledged by Arrow et al. (2012).

Finally, they tested two alternative indicators of future wellbeing: changes in the present value of per capita consumption as per Ferreira, et al. (2008); and changes in per capita real GDP. Hypotheses tests are conducted in conjunction with cointegration tests to capture the robustness of the results.

These tests are conducted over four different time horizons ie, 10, 15, 20 and 30 years. Hypotheses tests are also conducted for a set of increasingly comprehensive measures of capital stocks for New Zealand. Changes in the present values of real GDP per capita and changes in the present value of consumption per capita, are tested as alternative measures of wellbeing. For sensitivity analysis, they used two different discount rates, 1.4% and 2.8%.

Net National Savings, Green Series, Super Green Series and Genuine Savings Measures

For a further discussion of the data, methods and terminology refer to Appendix Genuine Savings. The increasingly comprehensive measures Net National Savings (NNS), Green Series, Super Green Series and Genuine Savings, TFP Green Series, TFP Super Green Series and TFP GS are illustrated in Figures 26-30. The values of all these measures in real terms and as a percentage of GDP were positive over the study period (ie, 1950 – 2015) although there was a large decline in these measures in 1975 because of the lowest value of net exports in the period of 1950 – 1987. Since then, there was an overall steady trend with some oscillations for all data series in real-terms except the SuperGreenSeries. This is mainly because of a sharp decline in a year-on-year changes in the forest volume.

Year-on-year changes in forest volume peaked in 1996, as shown in Figure 28, followed by a sharp decline in coming years as land use switched to dairy farming and agriculture as it became more profitable. This has subsequently resulted in the decline in the GS to GDP ratio since 1995 as shown in figure 27.

Figure 26 – Alternative measures of future wellbeing (real values per capita)

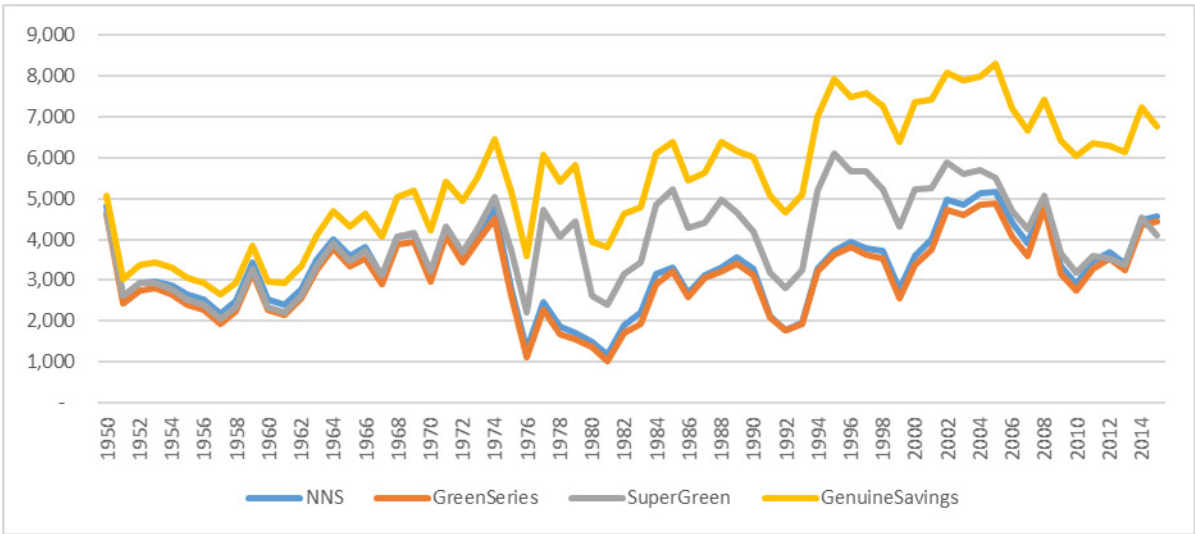


Figure 27 – Alternative measures of future wellbeing as % of GDP

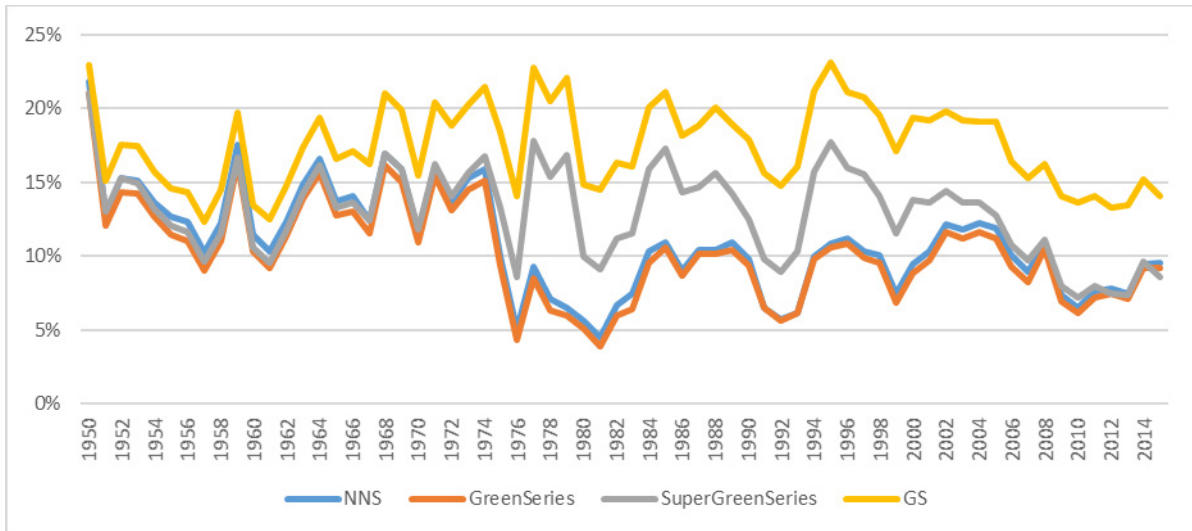


Figure 28 – New Zealand forest volumes

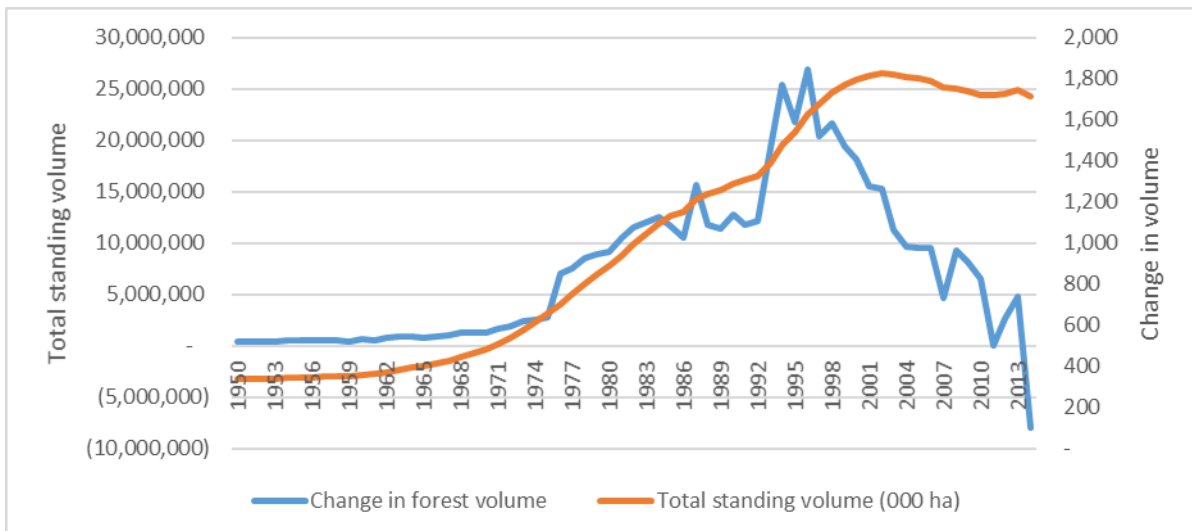


Figure 29 – PV of TFP series at 1.4% and 2.8% discount rate as % of GDP

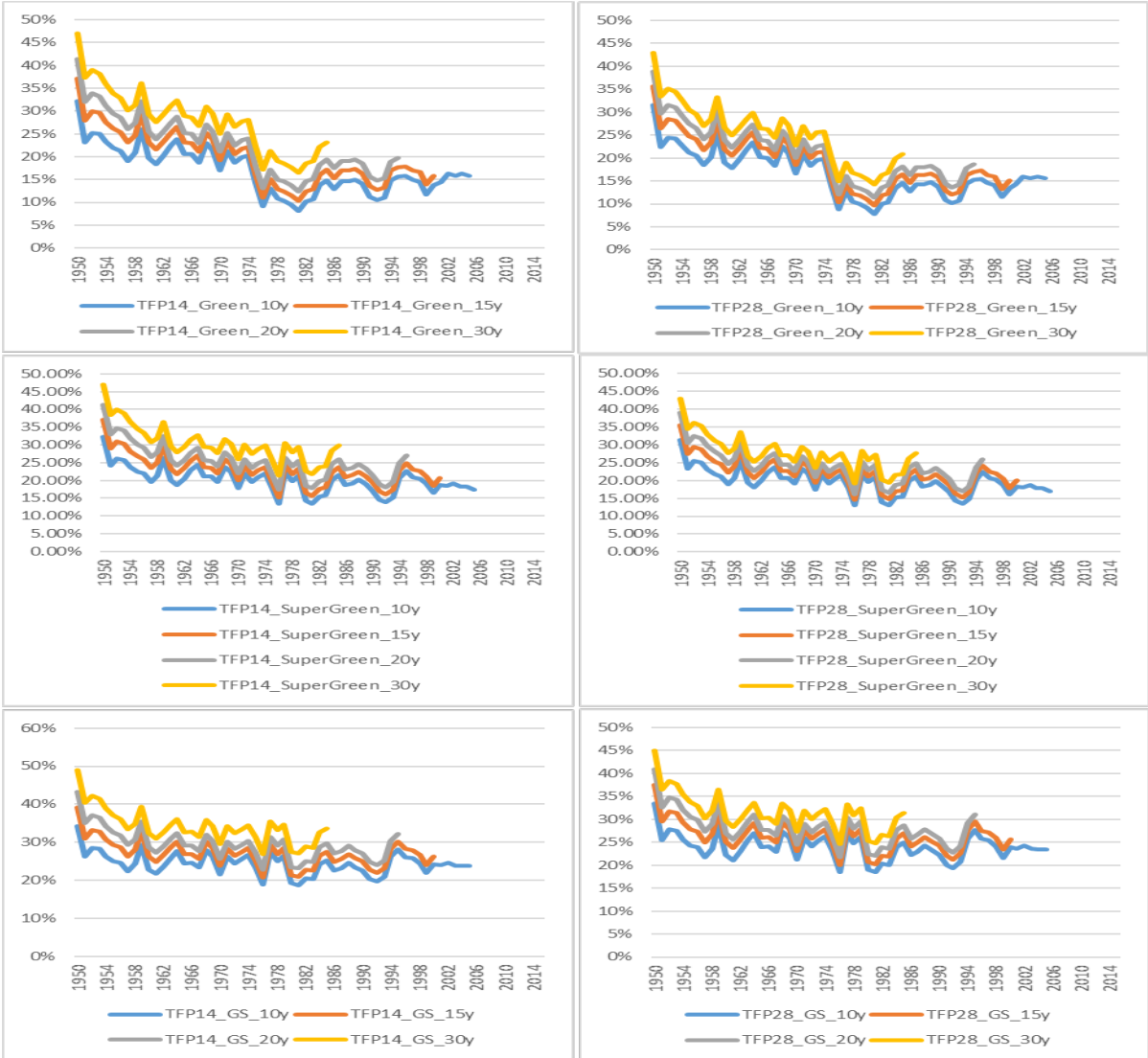
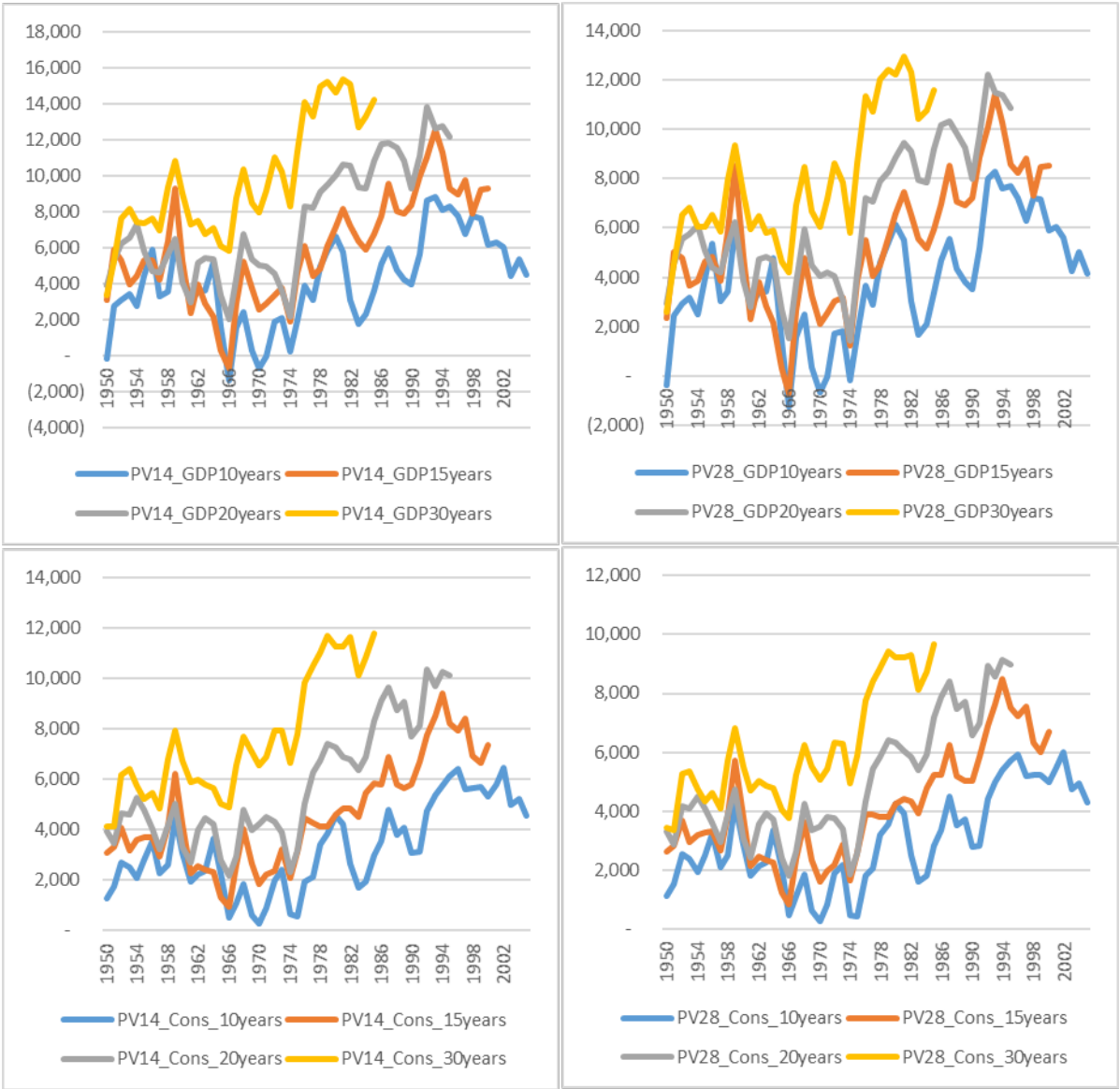


Figure 30 – PV of future changes in real GDP per capita and real consumption per capita at 1.4% and 2.8% discount rates



Measuring wellbeing over time

Oxley, Qasim and McLaughlin (2017) followed Ferreira et al., 2008 to calculate the net present values (NPVs) of consumption per capita and GDP per capita in real terms as measures of wellbeing. Both of these indicators align closely with the theoretical framework of GS. Data for these series are extracted from Stats NZ’s Info share from 1972 to 2015, and the older data were sourced from the New Zealand Official Yearbooks (NZOYBs). NPVs for these wellbeing measures are also calculated for four time horizons ie, 10, 15, 20 and 30 years using both 1.4% and 2.8% discount rates. Trends in these data series are summarised in Figure 30.

Empirical results

For two alternative measures of future wellbeing (real GDP per capita and real consumption per capita), our results align closely with the theoretical relationship between GS and future wellbeing, and provide support for the indicative capacity of the GS model, compared to previously published studies – New Zealand has been on a sustainable development path.

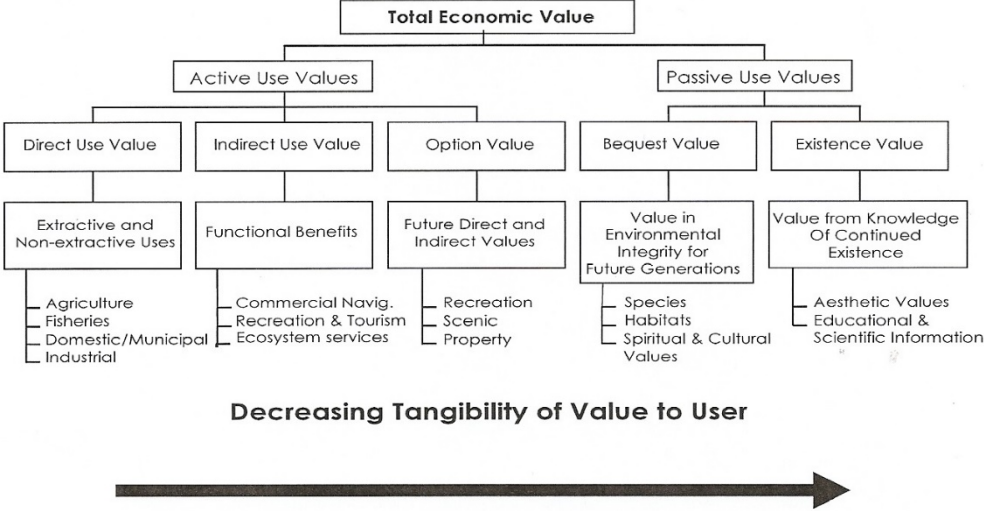
However, we note that models used to estimate whether a country is sustainable are hindered by the narrow breadth of good and robust data on the four capital stocks. Such significant data limitations mean that it is unclear whether New Zealand's previous and current development is sustainable or not.

Appendix 1: TEV examples

A gallery of TEV

Figure 31 shows a more detailed breakdown of TEV (drawing on the Canadian EVRI database categorisation) for valuing biodiversity, to be used by the Ministry for Agriculture and Fisheries (MAF) in its biosecurity functions. Figure 31 draws distinctions between active uses and passive uses, reflecting criticism that even non-use values reflect a decision to “use” the resource in a certain way. Active uses are further divided between direct uses which are predominantly those which extract things from the environment, and indirect uses that provide functional benefits to people with a mix of market and non-market values. Passive uses are divided between existence values and bequest values – altruistic value has disappeared. The values become less tangible the further to the right they lie on the diagram.

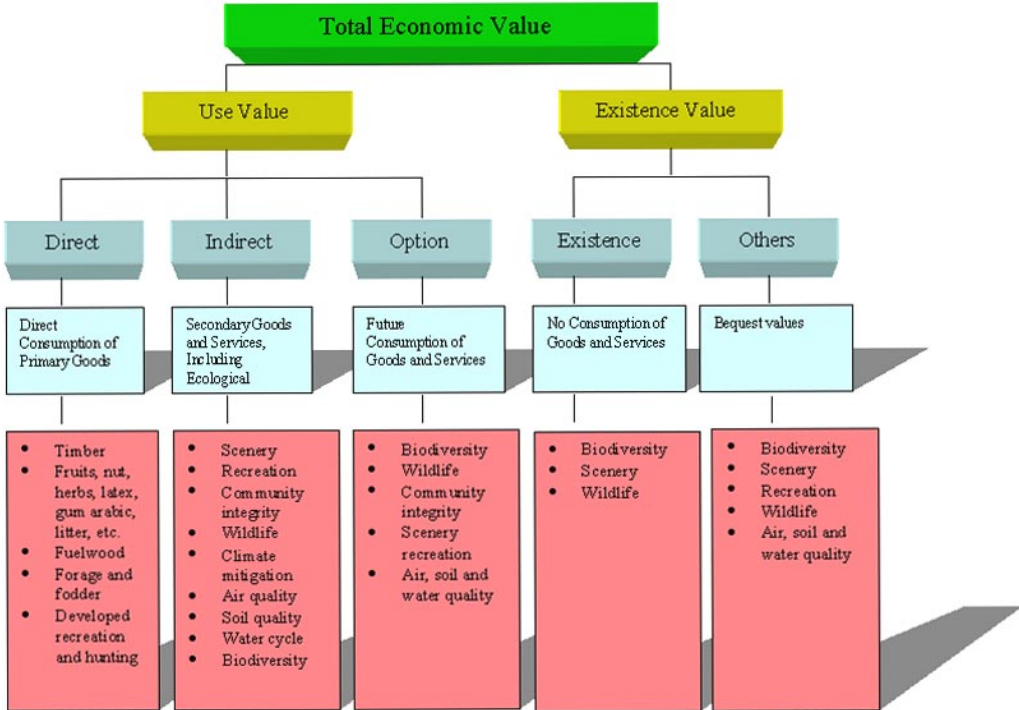
Figure 31 – TEV for Biodiversity



Source:(EVRI 2009)

Source: Nimmo-Bell (2011)

Figure 32 – Total Economic Value of Forests

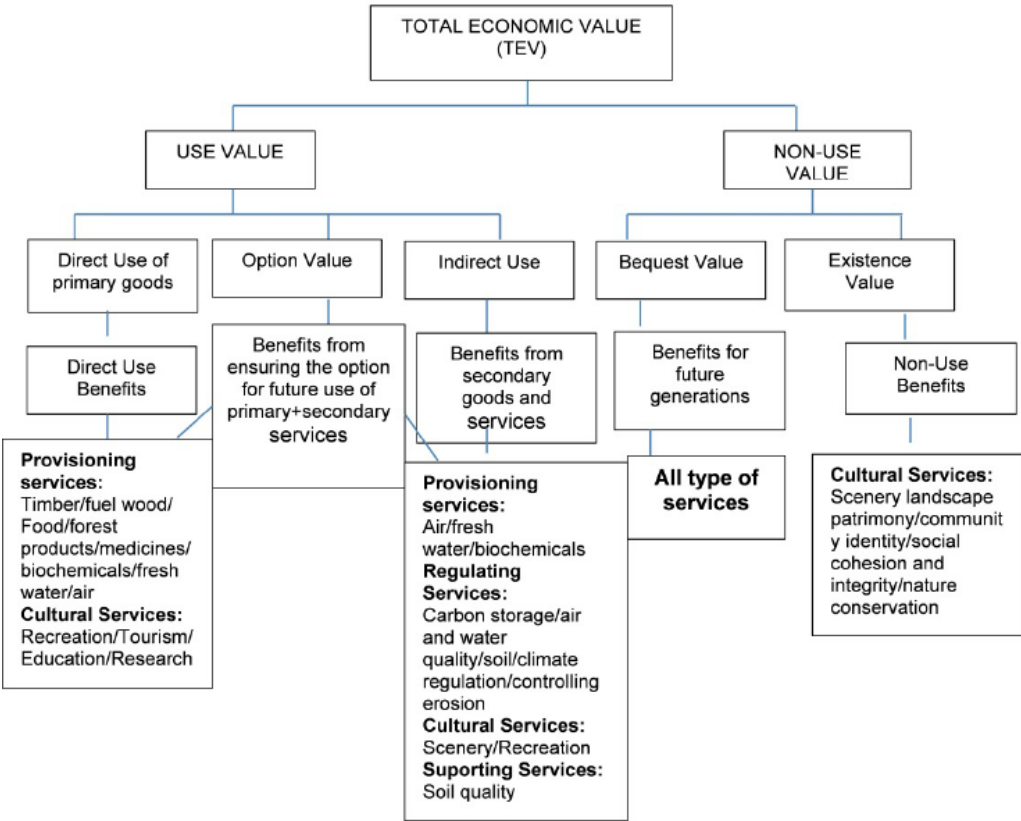


Source: FAO TEV of environmental resources (2002)

FAO reverts to distinguishing use value from existence value (in place of non-use value), but this is further divided between true existence value and others' value (ie, bequest value). At the lower level, direct use value includes consumption of primary goods and services from the environment, including that of developed recreation and hunting (ie, all things that potentially have commercial value). Indirect use value comes from secondary goods and services that support other activities or provide non-market benefits (such as unpriced recreation).

Figure 32 looks at another application of TEV to forests which also relates it to the ecosystems services framework. Thus, direct uses are provisioning services, indirect uses supply regulating services and some provisioning services, option values apply to future availability of both, while cultural services are split between direct use, indirect use and non-use value categories.

Figure 33 – TEV and ecosystem services



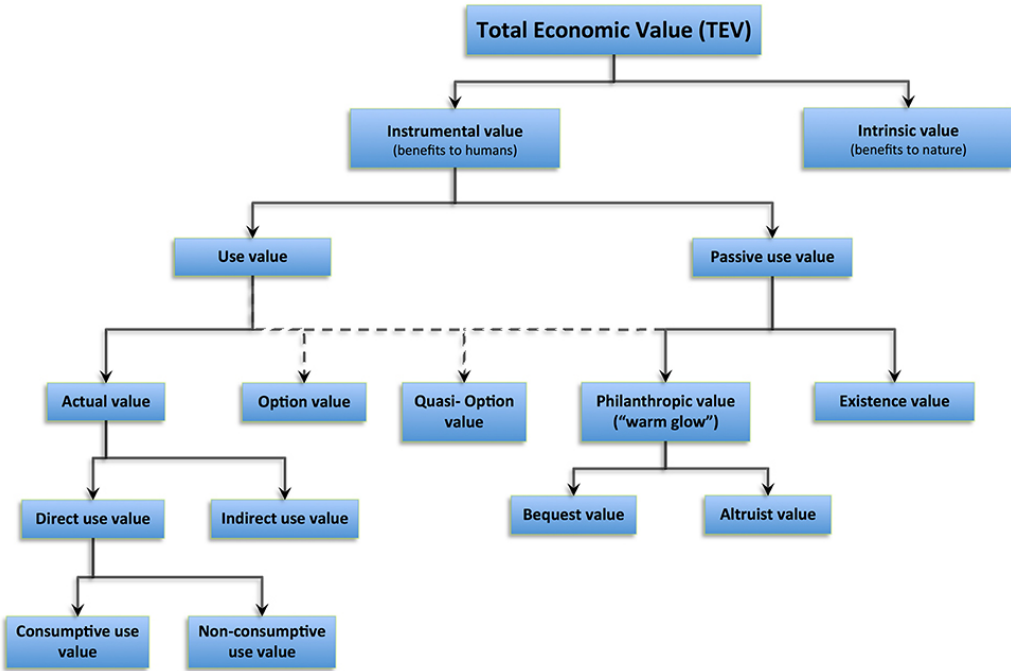
Source: Mendes (2012)

Pearce et al. (1989) in a relatively early exploration of the concept depicted TEV as the sum of total user value plus existence value, where:

- Total user value = actual use value plus option value
- Option value = value in use (by the individual in future) + value in use by future individuals (descendants and future generations) + value in use by others (vicarious value to the individual)
- Existence value = intrinsic value (value of an object for its own sake).

This formulation puts what later became known as bequest value (to future individuals) as a sub-set of option value rather than a non-use value. Further, the authors posit that the more a resource use choice has the following characteristics – irreversibility of change, uncertainty about future conditions and uniqueness of natural resource – the higher the value likely to be attached to its preservation.

Figure 34 – TEV and Components



Source: Baveye et al. (2016)

Figure 34 shows a more recent depiction of TEV, which makes a high level distinction between Instrumental value and intrinsic value, the instrumental value alone split between use values and passive use values. Direct use values are split between consumptive uses (like water abstraction) and non-consumptive uses (like in-stream recreation), and passive use values are shown with a different split between existence value and philanthropic value, the latter containing bequest value and altruist value. The philanthropic value is referred to as a “warm glow”, a term that is sometimes pejoratively used to describe actions to make people feel good without necessarily achieving much in tangible terms. It is not clear why the term should apply to bequest and altruistic value and not to existence value: in all cases they represent a willingness to pay over and above what would be rational in narrow self-interest terms.

Appendix 2: Valuation Techniques

Outline of valuation methods

A range of non-market valuation methods are used to quantify and monetise non-use values. This section provides an outline of the methods.

Market-based techniques

Market-based valuation means valuing an ecosystem good or service at the value at which it is exchanged in market transactions. In the case of recreation and tourism, this could include the price of entry to particular attractions (such as the National Trout Hatchery at Turangi) or the price of particular visitor services, including concession-supplied services. In New Zealand, such values are likely to be incomplete indicators of value of Crown-owned natural areas used for recreation and tourism, given the extent of unpriced use of such lands, including casual access or simply admiring the view.

Table 1 provides a broad typology of market- and cost-based approaches to valuing the natural environment. These all infer a value for the environmental change from some associated change in observed market activity. Mostly they infer a cost that would be incurred if the environment deteriorated, not the value that people might place on avoiding such deterioration, which may be greater than the expected avoided cost because of preference for peace of mind. Such techniques are therefore considered to give only a lower bound estimate of the value of the environment.

Table 1 – Market- and cost-based valuation approaches

Technique	Approach	Examples of use
Change in productivity	Value change in environment at the change in output associated with it	Costs of land degradation set at lost agricultural output value; benefits of lower factory noise levels valued at increased production from lower absenteeism
Change in income	Value change in environment at the change in incomes associated with it	Costs of air pollution valued at attributable health costs comprising lost productivity, increased medical expense and fatalities
Replacement cost	Value change in environment at cost of replacing equivalent natural resources elsewhere	Costs of replacing access to houses lost by re-routing a highway taken as a measure of benefits of maintaining access
Preventative expenditure	Value change in environment at observed cost of taking precautions against losing existing level of enjoyment	Cost of noise pollution inferred from households' willingness to pay for increased sound insulation, double glazing, baffle structures etc
Relocation expenditure	Value change in environment at observed cost of relocation to maintain existing level of enjoyment	Cost of congestion inferred from firms' and households' willingness to pay to relocate to less congested locations

Source: Commonwealth of Australia (1995)

Various methods may be used to estimate the costs and value changes in these approaches. There are also specific techniques that have been developed to standardise some of these, such as the Business Biodiversity Offset Programme which is an application of replacement cost approach.

Revealed preference (surrogate market) techniques

Non-market values can be estimated through what are known as revealed preference or “surrogate market” methods, which value an environmental asset by analysing market behaviour associated with its use. Two common revealed preference methods are travel cost analysis applied to valuing recreation sites, and hedonic pricing which has been applied to property values with respect to variations in property attributes or to wages with respect to variations in the risk associated with different jobs.

Travel cost analysis

The longest established non-market valuation technique applied to recreation is the travel cost method, which infers a price for unpriced recreation destinations from analysis of travel costs of a sample of those visiting each site. It is a two-stage process. First, a distance decay function is derived to establish the relationship between visitation and travel cost (mostly comprising travel distance costs, including travel time and fuel, but also including spending on ancillary services such as accommodation and other spending around the destination). This relationship is used to predict the visitation rates at changed levels of price, on the assumption that people would react to a destination entrance fee in the same way that they do to changes in travel expenses.

There are two variants of the travel cost method: the original “zonal” model in which concentric zones are established around the site and visitation is expressed as a rate per head of population in the zones; and a later “individual” method which uses more sophisticated analysis methods to estimate the probability of an individual from a given location visiting the site. The result in both cases is an estimate of a demand curve of visits at different levels of price, from which consumer surplus is derived.

The travel cost method was developed to deal with a particular type of recreation behaviour – single-destination visits from an origin to a destination site. It is less suited to multiple site trips, for which elaborate (but essentially arbitrary) procedures have been proposed for attributing shares of common trip costs to the different sites, usually based on the proportion of time spent at each site. Time spent at a location is not necessarily a good indicator of value placed on it: a “must-see” site that has limited capacity for doing things once there may be visited for only half an hour yet still attract a higher willingness to pay than intermediary stops along the way where people spend longer.

The presence of substitute sites that provide intervening opportunities between origins and destinations can be taken account of in the derivation of distance decay functions, but not all studies do this consistently. The recurring issue of how to attribute joint costs on multiple-site visits is particularly problematic with the cross-country tours commonly seen among international visitors to New Zealand (Kerr, Sharp and Gough 1986). The travel cost method is also rather limited in its depiction of marginal choices, as it effectively calculates consumer surplus at a point in time, presenting a value that would be lost if the site were removed in its entirety.

The common approach is to use the consumer surplus per visitor-day to estimate the value of small changes in capacity at the site, but it provides no guide to the value of other marginal changes in provision, such as changes in levels of crowding or the reconfiguration of access across the site. In short, although travel cost analysis says something about the value of the quantity of recreation taking place at a site, it is not informative about the marginal changes in the quality of provision for recreation.

Hedonic pricing

The other main revealed preference valuation technique is hedonic pricing, most commonly seen in regression analyses of house prices to isolate a price premium on proximity to a park or similar amenity. Whilst this could be taken as a valuation of the recreation opportunities of a park, the value premium can also be associated with more general amenity effects apart from recreation. Such analysis requires a large dataset of property values and the ability to control for other influential variables. It is most applicable to urban contexts and would not give the total value for recreation on sites that attract visitation from outside the immediate neighbourhood.

A hybrid approach is the hedonic travel cost method, which focuses on the choice of a recreation site from a given origin, rather than the set of visitor origins for a given site (Brown & Mendelsohn, 1984). However, this has not been used much and has received damning reviews for involving considerable inaccuracy and not providing useful information for many important policy questions (Bockstael & McConnell, 1998).

Stated preference (simulated market) techniques

Stated preference valuation techniques have also been widely applied to recreation, most commonly with respect to the value of particular sites or facilities. Although based on responses to hypothetical questions, the direct questioning has the potential to pick up values other than current use of particular sites (eg, option values and non-use values) and can be applied across a broader sample of the population than those who currently use the site. Recreation use varies through the family life cycle and the value placed on a site is not just dependent on those who currently use it, but also may include option and existence value across the wider population.

Contingent valuation and choice modelling are stated preference techniques that have been applied to recreation sites. Contingent valuation tends to be used as a substitute for travel cost analysis, in which the marginal choice is the continued availability or non-availability of the site in question, although sometimes such studies have also sought relative preferences for different future options for the site.

Choice modelling enables a considerably wider range of choices to be examined by establishing the relative values of different attributes of a site: it can be used for establishing a price for adding different components of a recreation site, such as open space, trails, facilities and so on, which gives it potential to be used in a wider range of management decisions than the simple demonstration of an economic value attached to the continued availability of the resource.

Contingent valuation

The contingent value method presents a sample population with a hypothetical situation to elicit direct responses on the willingness to pay for or willingness to accept (with compensation) the presented outcome. The method can be used to estimate use and non-use values: it has been used as a market research technique to estimate the prices that people would be willing to pay for improvements in public services or to fund payments for ecosystem services schemes, but its more distinctive use is to estimate non-use values. This method seeks to directly represent changes in utility with monetary values (Perman, Ma, Common, Maddison and McGilvray 2011). The responses can be weighted for sample population characteristics such as socio-economic factors.

Choice modelling

The method involves presenting survey respondents with a range of discrete alternatives and respondents are asked to choose their most preferred alternative. The outcomes and the cost alternatives are described in detail. The aim is to establish trade-offs respondents are making between the attributes and costs of the alternatives. Choice modelling is becoming more popular to measure non-use values, because its use of implicitly asking about costs trade-offs tends to yield greater respondent participation rates compared to asking for explicit value as in contingent valuation. Choice modelling can also be more informative than contingent valuation about the marginal value from small changes in the attribute mix.

Conjoint analysis

Conjoint analysis aims to elicit preferences from the sample population, rather than monetary values, by presenting them with choices or trade-offs for a range of options with different characteristics or costs. Conjoint analysis allows researchers to infer social preferences and ranking of options and outcomes associated with use or non-use of natural capital without having to assign monetary values. This method may be used in informing the Investment Statement about the relative priority society places on types of natural capital, but may not necessarily provide estimates of the value of natural capital. The emphasis on establishing trade-offs, rather than monetary values, is more akin to the information used for policy formulation than for the broad purposes of the Investment Statement.

Appendix 3: Genuine Savings

Data and methods

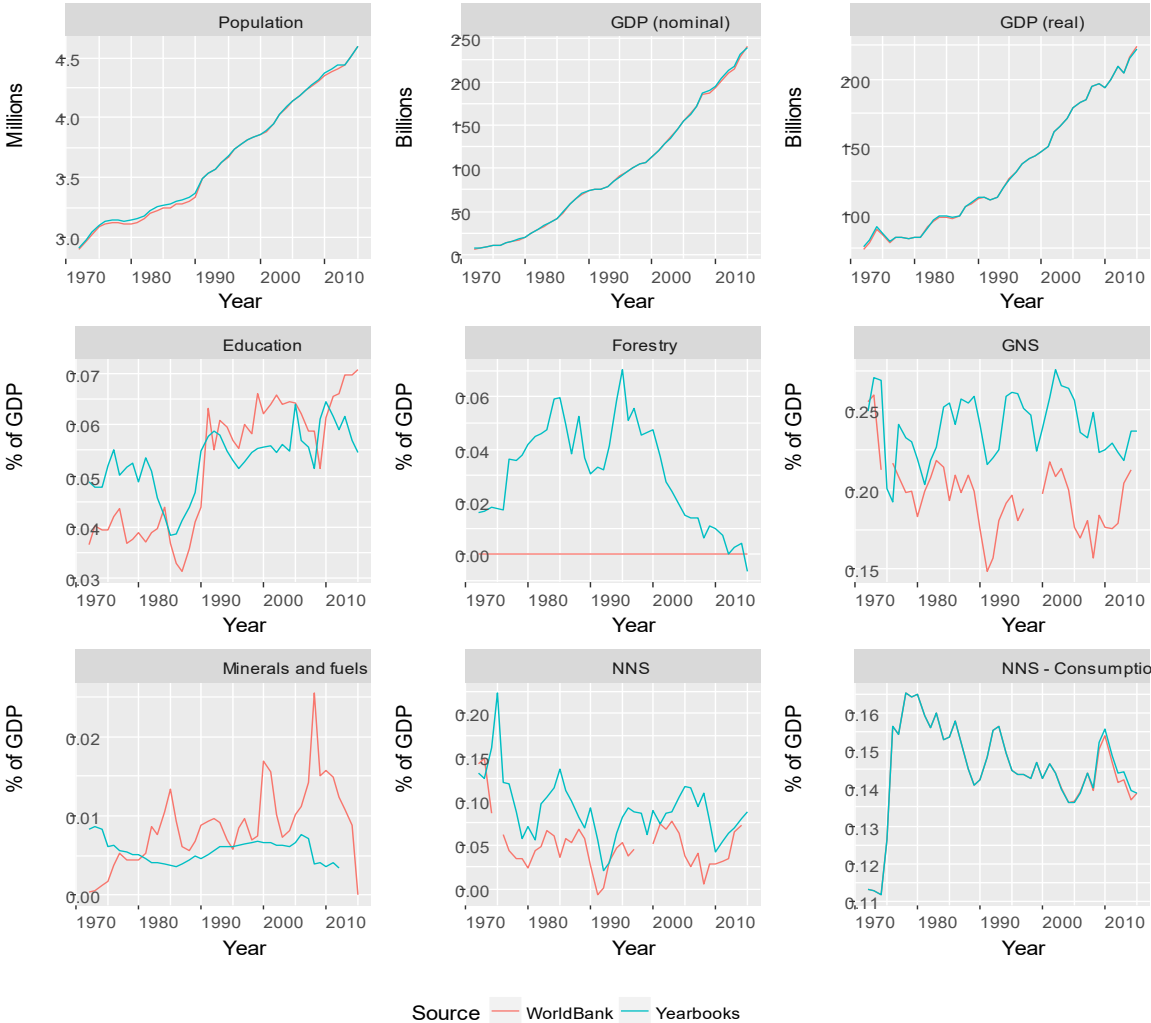
The results presented below are based on New Zealand time-series data, 1950 – 2015 compiled from several national databases and publications. Variables are described in detail with data sources and descriptive statistics in the data appendix. As a starting point, they briefly compared our key statistics with corresponding measures of Adjusted Net Savings (ANS) available from the World Bank databank for New Zealand. Table 2 and Figure 35 below present those comparisons. This initial first step is important as an introduction as to why our results may differ from those previously published by the World Bank, in particular, in addition to a longer time span being covered in our work, we also use data that in some cases are somewhat crudely approximating variables that can be better proxied and also we include some important data (eg, on forestry) that were omitted from the World Bank modelling and estimation.

The World Bank (2017) has been publishing annual GS rates for a panel of approximately 160 countries including New Zealand. We compare averages of key variables in the GS model based upon our estimates and the World Bank’s estimates, and present the results as Table 2. The mean values of gross capital formation, consumption of fixed capital, education expenditure nominal GDP and population are very similar with very small differences, whereas the mean values of the remaining variables are often quite different. Two key factors are responsible for these differences: firstly, different data sources; and secondly, slight differences in estimation methods.

Table 2 – Comparison of averages of key variables between Oxley, Qasim and McLaughlin (2017) estimates and the World Bank’s estimates

Variable	As mean percentage of nominal GDP (otherwise specified) Between 1972 – 2015		Comment on source
	World Bank (2017)	Oxley, Qasim & McLaughlin (2017) estimates	
Gross national savings	19.63%	23.97%	Different data sources
Net national savings	5.00%	9.06%	Different data sources
Gross capital formation	23.66%	23.63%	
Gross national savings	19.63%	23.16%	Different data sources
Consumption of fixed capital	14.62%	14.57%	Different data sources
Minerals and energy	0.86%	0.56%	Different data sources
Forestry	NA	3.11%	Different data sources
Education expenditure	5.21%	5.30%	Different data sources
Mean of nominal GDP (millions)	95,896	95,877	Different data sources
Mean of population (millions)	3,65	3,66	Different data sources

Figure 35 – Time series comparisons of key variables between Oxley, Qasim and McLaughlin estimates and the World Bank’s estimates



For example, our main data sources are New Zealand national statistical yearbooks and other national databases, whereas the World Bank’s key data sources are international databases. In addition, the World Bank’s estimates do not include forestry in their GS model. This might be either because they want to maintain comparability between the panel of 160 countries or owing to lack of data availability. We have compiled two new measures, Green and super green series, discussed in the later part in detail, to take these missing forestry data into account. The incorporation of the missing forestry data plays a vital role in considering the sustainability of the New Zealand’s economy and future wellbeing as a whole. From these data we construct increase comprehensive savings measures as potential predictors of future wellbeing:

- 1 Net national savings (NNS)
- 2 Green series
- 3 Super green series
- 4 Genuine savings (GS), and
- 5 TFP series for green, super green and GS series.

Net national savings (NNS)

According to the World Bank methodology (Bolt, Matete, & Clemens, 2002), gross national savings (GNS) are calculated as the difference between gross national income and public and private consumption plus net current transfers (savings are seen as the “residual” and not measured directly). NNS is calculated as the difference between gross national savings and depreciation/consumption of fixed capital (CFC). For this study, data for GNS and CFC are available from Stats NZ. There has been an increasing trend in the value of NNS per capita over the period series 1950 – 2015, but with some fluctuations.

Green series

The New Zealand economy has been benefited in a GDP sense from the extraction of non-renewable metal and mineral resources. There has been a rise in activity in the mining industry in recent years and this industry’s contribution to GDP has risen by approximately 1% since 2007.

Super green series

Forestry is a significant industry in New Zealand as it has been contributing to an average of 3.4% of GDP annually over the period of this study, which is more than double that of the contribution to GDP from all other natural resources combined. Exports from forestry are estimated to reach \$4.8 billion in 2017, which is almost tripled merchandised exports (NZIER, 2017).

In addition, New Zealand forests are a strong carbon sink (Hollinger, Maclaren, Beets & Turland, 1993, Tate et al., 2000) which makes the “damages from carbon dioxide emissions” less relevant to our GS model.

Genuine savings (GS)

GS is obtained from the sum of super green series and investments in education as a proxy of human capital as per the World Bank methodology. Data for government spending on education at all levels (ie, including primary, secondary, tertiary, etc.) are obtained from the New Zealand Official Yearbooks (NZOYBs) for the period 1950 – 1971 and from Stats NZ for 1972 – 2015. There are certain pros and cons of using education expenditure to a proxy of human capital. Government spending on education naturally fits into the GS framework, which articulates the varying components of investment. Nevertheless, human capital formation does not equate to spending on education (Hanley et al., 2016). For instance, human capital includes the skill set acquired in the workplace, voluntary online learning, etc. In addition, international migration of educated New Zealanders plays a vital role in terms of human capital available to the country. However, the brain drain from New Zealand is offset by the incoming professional immigrants to New Zealand which, many researchers see as brain exchange rather than brain drain (Glass & Choy, 2001).

A Total Factor Productivity (TFP) series for green, super green and GS measures

Fagerberg (2000) shows that New Zealand achieved a total TFP growth of 51.3% between, 1973 – 1990 with an average annual growth of 2.4%. Similarly, Färe, Grosskopf and Margaritis (2001) studied relative TFP trends for Australia and New Zealand manufacturing sectors and concluded that New Zealand’s TFP record in this sector has been slightly better on average than that of Australia. Trend growth TFP estimates can be used to support the valuation of exogenous technological progress.

References

- Arrow, K.J., Dasgupta, P., Goulder, L.H., Mumford, K.J. & Oleson, K. (2012). "Sustainability and the measurement of wealth". *Environment and Development Economics*, 17(03), 317–353. doi:10.1017/S1355770X12000137
- Asheim, G.B.(1994). "Net National Product as an Indicator of Sustainability". *The Scandinavian Journal of Economics*, 96(2), 257-265
- Au, J. & Karacaoglu, G. (2015). "Using the Living Standards Framework: Update and policy examples", *New Zealand Journal of Sociology*, 30(3), 27-40.
- Baveye, P.C., Baveye,J. & Gowdy, J. (2016). "Soil ecosystem services and cultural capital: Critical appraisal of research on uncertain ground" *Frontiers in Environmental Science* <https://doi.org/10.3389/fenvs.2016.00041>
- Blum, M., McLaughlin, E. & Hanley, N. (2013). "Genuine savings and future well-being in Germany, 1850-2000". Sterling, University of Sterling/
- Bockstael, N.E. & McConnell, K.E. (1998). "Revisiting the hedonic travel cost model". Working Paper WP 98-09, *Department of Agriculture and Resource Economics*, Baltimore, University of Maryland.
- Bolt, K., Matete, M. & Clemens, M. (2002). "Manual for calculating adjusted net savings." *Environment Department*, Washington DC, World Bank.
- Brown, G. & Mendelsohn, R. (1984). "The Hedonic Travel Cost Method", *The Review of Economics and Statistics*, 66(3), 427-433.
- Commonwealth of Australia (1995)."Techniques to value environmental resources", *Department of Environment, Sport and Territories and the Department of Finance*.
- Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., et al. (1997). "The Value of the World's Ecosystem Services and Natural Capital". *Nature* 387: 253–60.
- Dasgupta, P. & Mäler, K.G. (2001). "Wealth as a criterion for sustainable development". Stockholm, Citeseer.
- Department of Conservation (2017). "Threatened species strategy". <http://www.doc.govt.nz/pagefiles/169845/threatened-species-strategy-draft.pdf>
- Dietz, S. & Neumayer, E. (2007). "Weak and strong sustainability in the SEEA: Concepts and measurement". *Ecological Economics* , 61(4), 617 – 626. doi:http://dx.doi.org/10.1016/j.ecolecon.2006.09.007
- Ducoing Ruiz, C., Blum, M. & McLaughlin, E. (2016). "A Sustainable Century? Genuine Savings in developing and developed countries, 1900-2000". Scotland, St Andrews University.
- Ekins, P., Sandrine, S., Deutch, L., Folke, C. & De Groot, R. (2003). "A framework for the practical application of the concepts of critical natural capital and strong sustainability". *Ecological Economics*, 44(2), 165-185
- Fagerberg, J. (2000). "Technological progress, structural change and productivity growth: a comparative study". *Structural change and economic dynamics*, 11(4), 393-411.
- Färe, R., Grosskopf, S. & Margaritis, D. (2001). "Productivity trends in Australian and New Zealand manufacturing". *Australian Economic Review*, 34(2),125-134

- Ferreira, S., Hamilton, K. & Vincent, J.R. (2008). "Comprehensive Wealth and Future Consumption: Accounting for Population Growth". *World Bank Economic Review*, 22(2), 233-248.
- FAO TEV of environmental resources (2002). "Total Economic Value of Forest Resources in Turkey", Italy, FAO. <http://www.fao.org/docrep/article/wfc/xii/0410-a2.htm>
- Forum for the Future (2013). "Natural capital stocks and flows" <https://www.forumforthefuture.org/>
- Forum for the Future (2014). "The Five Capitals Model – a framework for sustainability" <https://www.forumforthefuture.org/project/five-capitals/overview>
- Glass, H., Choy, W.K. (2001). "Brain drain or brain exchange?". Wellington, The Treasury.
- Global Nature Fund (2012). "How Business Values Natural Capital". Radolfzell (Germany), International Foundation for the Protection of Environment and Nature.
- Greasley, D., Hanley, N., Kunnas, J., McLaughlin, E., Oxley, L. & Warde, P. (2014). "Testing genuine savings as a forward-looking indicator of future well-being over the (very) long-run". *Journal of Environmental Economics and Management*, 67(2), 171 – 188. doi:<http://dx.doi.org/10.1016/j.jeem.2013.12.001>
- Hamilton, K. (1994). "Green adjustments to GDP". *Resource Policy*, 20(3), 155-168. doi:[http://dx.doi.org/10.1016/0301-4207\(94\)90048-5](http://dx.doi.org/10.1016/0301-4207(94)90048-5)
- Hamilton, K. & Clemens, M. (1999). "Genuine Savings Rates in Developing Countries". *World Bank Economic Review*, 13(2), 333-356.
- Hamilton, K. & Atkinson, G. (2006). "*Wealth, welfare and sustainability: Advances in measuring sustainable development*". Cheltenham, Edward Elgar Publishing.
- Hanley, N., Oxley, L., Greasley, D.M.E. & Blum, M. (2016). "Empirical Testing of Genuine Savings as an Indicator of Weak Sustainability: A Three-Country Analysis of Long-Run Trends". *Environmental and Resource Economics*, 63(2), 313-338.
- Hartwick, J.M. (1977). "Intergenerational equity and the investing of rents from exhaustible resources". *American economic review*, 67(5), 972–974.
- Hartwick, J.M. (1990). "Natural resources, national accounting and economic depreciation". *Journal of Public Economics*, 43(3), 291 – 304. doi:[http://dx.doi.org/10.1016/0047-2727\(90\)90002-Y](http://dx.doi.org/10.1016/0047-2727(90)90002-Y)
- Helm, D (2015). "*Natural Capital – Valuing Our Planet*", London, Yale University Press.
- Hollinger, D., Maclaren, J., Beets, P. & Turland, J. (2013). "Carbon sequestration by New Zealand's plantation forests." *New Zealand Journal of Forestry Science*, 23(2), 194-208.
- Kerr, G.N., Sharp, B.M. & Gough, J.D. (1986). "*Economic benefits of Mt Cook National Park*". *Centre for Resource Management*, Christchurch, University of Canterbury and Lincoln College
- Mendes, I. (2012). "Economic valuation as a framework incentive to enforce conservation", *Protected Area Management*, In Tech Publishers.
- Millennium Ecosystem Assessment (2005). "*Ecosystems and Human Well-being: Synthesis*". Washington, D.C., Island Press <http://www.millenniumassessment.org/documents/document.356.aspx.pdf>
- Ministry for the Environment (2005). "TEV framework – Waitaki Catchment example" <https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/Option%20and%20existence%20values%20for%20the%20Waitaki%20Catchment.pdf>

- NZIER (2017). "Plantation forestry statistics: Contribution of forestry to New Zealand". Wellington, The Treasury.
- Nimmo-Bell (2011) for MAF Biosecurity New Zealand. "TEV for Biodiversity". Wellington: Nimmo-Bell <http://www.nimmo-bell.co.nz/pdf/ManualRev29411.pdf>
- OECD (2006). "Cost benefit analysis and the environment: some recent developments", Paris, Organisation of Economic Co-operation and Development
- OECD (2013). "Guidelines on measuring subjective well-being". Paris, Organisation of Economic Co-operation and Development <http://www.oecd.org/statistics/oecd-guidelines-on-measuring-subjective-well-being-9789264191655-en.htm>
- OECD (2015). "How's Life: Measuring Well-being". Paris, Organisation of Economic Co-operation and Development <http://www.oecd-ilibrary.org/docserver/download/3014021e.pdf?expires=1510009752&id=id&accname=ocid56017414&checksum=06205C71A888D14D2CA30321096C272D>
- Office for National Statistics (ONS) (2015). "2015 Roadmap". London, Office for National Statistics. <https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/methodologies/naturalcapital>
- Oxley, L., Qasim, M., & McLaughlin, E. (2017). "Genuine Savings as a Test of New Zealand Weak Sustainability". Wellington, The Treasury.
- Pagiola S, von Ritter, K., Bishop J. (2004). "Assessing the Economic Value of Conservation". Washington, D.C., The World Bank.
- Pearce, D.W., Markandya, A. & Barbier, E.B. (1989). "Blueprint for a Green Economy". London, Earthscan Books.
- Pearce, D.W. & Atkinson, G.D. (1993). "Capital Theory and the Measurement of Sustainable Development: An Indicator of Weak Sustainability". *Ecological Economics*, 8(2), 103 – 108. doi:[http://dx.doi.org/10.1016/0921-8009\(93\)90039-9](http://dx.doi.org/10.1016/0921-8009(93)90039-9)
- Perman, R., Ma, Y., Common, M., Maddison, D. & McGilvray, J. (2011). "Natural Resource and Environmental Economics". London, Pearson Education Ltd.
- Pezzey, J.C.V. (2004). "One-sided sustainability tests with amenities, and changes in technology, trade and population". *Journal of Environmental Economics and Management*, 48(1), 613 – 631. doi:<http://dx.doi.org/10.1016/j.jeem.2003.10.002>
- Pezzey, J.C.V., Hanley, N., Turner, K. & Tinch, D. (2006). "Comparing augmented sustainability measures for Scotland: Is there a mismatch?" *Ecological Economics*, 57(1), 60-74.
- Quiggin, J. (1997). "Discount rates and sustainability". *International Journal of Social Economics*, 24(1/2/3), 65–90. MCB UP Ltd.
- Romero, J.C. & Linares, P. (2014). Exergy as a global energy sustainability indicator. A review of the state of the art. *Renewable and Sustainable Energy Reviews*, 33(0), 427-442.
- Solow, R.M (1974). "The Economics of Resources or the Resources of Economics". *The American Economic Review*, 64(2), 1-14
- Stats NZ (2002). "Environmental Economic Accounts" http://archive.stats.govt.nz/browse_for_stats/environment/environmental-economic-accounts.aspx
- Stats NZ (2008). "Stats NZ's Framework for Measuring Sustainable Development" <http://archive.stats.govt.nz/~media/Statistics/.../environment/.../ffmsd.pdf>

- Stats NZ (2015). "Asset value of water and other renewables for electricity generation: 2007-15"
http://archive.stats.govt.nz/browse_for_stats/environment/environmental-economic-accounts/renewables-account-2007-15.aspx
- Tate, K., Scott, N., Parshotam, A., Brown, L., Wilde, R., Giltrap, D., Trustrum, N., et al. (2002). "A multi-scale analysis of a terrestrial carbon budget: is New Zealand a source or sink of carbon?". *Agriculture, ecosystems & environment*, 82(1),229-246.
- TEEB – The Economics of Ecosystems and Biodiversity for National and International Policy Makers (2009). "Responding to the value of nature". Wesseling, Welzel and Hardt
- Ten Brink, P. (2008). "Review of Economics of Biodiversity". Brussels, United Nations.
- UK National Ecosystems Assessment (UK NEA, 2011). "UK National Ecosystem Assessment", London, <http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx>
- UK National Ecosystem Assessment Follow-on (UK NEAFO, 2014). "UK National Ecosystem Assessment Follow-on", London, UK National Ecosystems Assessment.
<http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx>
- UK Natural Capital Committee (2014). "The State of Natural Capital – Restoring Our Assets". London, The Natural Capital Committee.
- Wealth Accounting and Valuing Ecosystems Services (Waves, n.d, 2017) "Valuing Natural Capital for Sustainable Development". Washington D.C., Waves.
<https://www.wavespartnership.org/en>
- World Bank (2017). "The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium", Washington, D.C., The World Bank.
- World Commission on Environment and Development (WCED, 1987). "Report of the World Commission on Environment and Development – Our Common Future", Geneva, United Nations. <https://sustainabledevelopment.un.org/milestones/wced>