



# The interrelationship of green infrastructure and natural capital

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## ARTICLE INFO

### Keywords:

Green infrastructure  
Natural capital  
Ecosystem services  
Constructed wetlands

## ABSTRACT

The terms green infrastructure and natural capital are interrelated. Natural capital as a concept is focused upon environmental assets which can provide ecosystem services, either directly or indirectly to humans; the concepts of natural capital and ecosystem services emphasize the benefits humans obtain from the natural environment. Green infrastructure is a concept with a wide range of definitions. The term is sometimes applied to networks of green open spaces found in or around urban areas. In other contexts green infrastructure can describe alternative engineering approaches for storm water management, with co-benefits of temperature control, air quality management, wildlife habitats and/or recreation and amenity space. No environments are completely free of human influence and therefore no environments are entirely natural. Rather, there is a spectrum of degrees of 'naturalness' ranging from environments with minimal human influence through to built environments. A trio of case studies presented herein illustrates how green infrastructure projects are a practical application of the natural capital concept in that they seek to preserve and enhance natural capital via a management approach which emphasizes the importance of environmental systems and networks for the direct provision of ecosystem services to human populations. Natural capital forms critical components of all green infrastructure projects.

## 1. Introduction

Capital is a stock which possesses the capacity to give rise to a flow of goods and services. Classical economics identify land, labour and human-made capital as the different types of capital stocks (Smith, 2008). In the modern context, Ekins et al. (2003) describe four kinds of capital: (i) *manufactured capital*, made up of material goods such as machines or infrastructure which contribute to production processes, (ii) *human capital*, made up of individuals and their capacity to work, (iii) *social and organisational capital* consisting of networks which allow the mobilisation of inputs from individuals, and (iv) *ecological capital*, also called *natural capital*, which provides resources for production, absorbs wastes, provides the underlying conditions which allow production to proceed and contributes more broadly to human welfare. Natural capital roughly corresponds with the classical economics factor of production of land (Costanza and Daly, 1992) and is the focus of this article. Crossman and Bryan (2009) link natural capital with ecosystem

services, defining it as “the stock from which ecosystem goods and services are provided”. Earlier, Hinterberger et al. (1997) suggest that nature can be seen as capital and the services provided by nature as income. Thus, natural capital is related to but different to ecosystems services, which can be defined as “the aspects of ecosystems utilized (actively or passively) to produce human well-being” (Fisher et al., 2009).

The concept of natural capital has grown in prominence in recent years, with bodies such as the UK's Natural Capital Committee and the Natural Capital Initiative being established in the UK, and internationally, bodies such as the Natural Capital Coalition, and the World Forum on Natural Capital, together with hundreds of journal articles published which discuss natural capital. Along with the concept of natural capital, the term ‘green infrastructure’ has also gained prominence, and as with natural capital, a variety of definitions of this term are used. For example, Naumann et al. (2011, p1) describe green infrastructure as “the network of natural and semi-natural areas, features

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<https://doi.org/10.1016/j.landusepol.2018.03.021>

Received 12 April 2017; Received in revised form 7 March 2018; Accepted 7 March 2018  
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and green spaces in rural and urban, and terrestrial, freshwater, coastal and marine areas, which together enhance ecosystem health and resilience, contribute to biodiversity conservation and benefit human populations through the maintenance and enhancement of ecosystem services”.

The aim of this article is to evaluate the concepts of natural capital and green infrastructure to assess the extent to which they interrelate. As argued by Ekins et al. (2003), “[n]atural capital is a metaphor to indicate the importance of elements of nature..... to human society”, with critical natural capital that which sustains key environmental functions and which cannot be substituted by manufactured capital for sustaining these functions. Green infrastructure similarly is a metaphor indicating the importance of key components of the environment (Abhijith et al., 2017) and also directly emphasizes the critical services provided by these components due to its analogy with constructed infrastructure that is vital to urban living (Thomas and Littlewood, 2010; Tiwary and Kumar, 2014). Following a review of the natural capital and green infrastructure concepts, this article analyses how the concepts of green infrastructure and natural capital overlap and the implications of considering these two terms together. Three green infrastructure case studies are then analysed from a natural capital perspective to inform a discussion of the usefulness of these concepts and their interrelationship.

## 2. The concept of natural capital

Rather than try to define natural capital in precise terms, some researchers provide examples of what they mean by the term. Thus, Schumacher (1973, p5) in one of the earliest direct uses of the term ‘natural capital’ gives as an example fossil fuels while noting in relation to human-made capital that “[f]ar larger is the capital provided by nature and not by man”. Cleveland (1994) gives examples such as stands of timber, the operation of the hydrologic cycle, fossil fuels and mineral deposits. The World Bank (2011) gives the examples of agricultural land, protected areas, forests, minerals, and energy, while Brand (2009) gives the examples of ecosystems, air and water. Berkes and Folke (1994) give examples of oil and minerals, fish, wood and drinking water, along with environmental services such as the maintenance of the atmosphere and the operation of the hydrological cycle. However, such environmental services are arguably the product of natural capital rather than natural capital itself, suggesting that the concept of natural capital is closely tied up with that of ecosystem services. Human wellbeing is derived from the ecosystem services stemming from the interaction of natural capital with other forms of capital.

The UK’s Natural Capital Committee (2017b, p1) defines natural capital as “the elements of the natural environment which provide valuable goods and services to people, such as clean air, clean water, food and recreation”. Along similar lines, the Natural Capital Coalition (2016) defines natural capital as the stock of natural resources (renewable and non-renewable) that yield a flow of benefits to people. Costanza and Daly (1992, p38) also define natural capital as a natural stock “that yields a flow of valuable goods and services into the future”. Costanza and Daly go on to distinguish between renewable and non-renewable natural capital. Whereas renewable natural capital is active and self-maintained via solar energy, non-renewable natural capital is passive, generally yielding no services until it is extracted. Examples of renewable natural capital include forest ecosystems yielding a flow of services, such as recreational space and erosion control, but can also be harvested to yield goods, such as wood. Non-renewable natural capital includes fossil fuels and minerals (Costanza and Daly, 1992). Most definitions of natural capital perhaps unsurprisingly emphasize “natural” as the defining element; Daly (1994) argues that unlike other forms of capital, natural capital cannot be produced by humans. Segura and Boyce (1994) suggest that designation of natural resources as “natural capital” has occurred because the availability of natural resources can

no longer be taken for granted, with their depletion needing to be treated as a cost.

### 2.1. Valuing of natural capital

Since one of the key reasons for the development of the concept of natural capital is to highlight its importance to human societies, monetary valuations can be used to reveal its value relative to other forms of capital. However, the real value of natural capital is reflected to only a limited extent by market prices and so non-market valuation techniques are frequently used (Farley, 2008). As the UK’s Natural Capital Committee (2017a) argues, decisions about natural capital investment may not provide the best outcome for society if they are based upon market prices alone.

The use of non-market valuation techniques, however, raises the question of whether a single metric can adequately capture the multiple attributes of natural capital (Farley, 2008). As Chiesura and de Groot (2003) argue, while economists use monetary units for valuing natural capital, natural scientists quantify natural capital using physical units. However, using physical units to quantify natural capital presents challenges when trying to determine whether natural capital stocks are increasing or decreasing as it is problematic to sum up very different physical components, while monetary units provide a common metric to quantify stocks (Hinterberger et al., 1997).

Despite the methodological challenges of using physical units for valuing natural capital, for some forms of natural capital, such as endangered species, estimating value in monetary terms can be seen as unacceptable (Farley, 2008). Even putting aside principled objections, there are serious methodological concerns with non-market valuations based upon methods such as stated preferences and revealed preferences. Not only can these seriously underestimate values, their application involves normative assumptions about who should participate in decision making (Farley, 2008).

Previous studies note that monetary valuations of natural capital can face the problem that sharp reductions in capital can be outweighed by higher prices (Hinterberger et al., 1997). Arrow et al. (2012) propose the use of shadow pricing for valuing capital gains in non-renewable natural capital. Farley (2008) however, argues that for natural capital which is approaching the threshold of criticality, monetary valuations may be inappropriate as capital stocks can change faster than the valuation and decision making processes proceed. Despite the methodological challenges, natural capital valuations have been included in comprehensive wealth accounting studies developed by the World Bank and other institutions (UNU-IHDP and UNEP, 2012; World Bank, 2011).

### 2.2. Natural capital and the natural-manufactured spectrum

While natural capital can be defined as the stock from which ecosystem goods and services are provided, natural capital is not necessarily “natural” in the sense of being free of human influence. In relation to soil natural capital stocks, for example, Dominati et al. (2010) distinguish between inherent soil properties (such as slope, depth and clay type), and manageable soil properties—characteristics which respond to active management (such as contents of nutrients and organic matter and macro-porosity). While inherent soil characteristics cannot easily be altered, farmers and other land managers can optimise manageable soil properties to maximise particular ecosystem service outputs such as human food provision. Likewise, Robinson et al. (2013) argue that virtually all ecosystems are shaped in some way by humans, while some are even created by humans, and so identifying truly natural capital is difficult. Crossman and Bryan (2009) also note that over-exploited agricultural land requires management or land-use change in order to restore its depleted natural capital stock, observing that some natural capital can be the result of determined human effort. Similarly, Segura and Boyce (1994, p480) and Hinterberger et al. (1997, p4) suggest that humans can “invest in natural capital” through measures

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