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Living with Environmental Limits

Natural resources such as land, water, soil, plants and animals should be used and managed within boundaries that allow the resource to renew itself. Otherwise, well-being, for present and future generations, will be impacted. This POSTnote summarises a longer POST report on environmental limits, which sets out the challenges to achieving this aim, whilst considering the complex trade-offs between social, economic and environmental objectives.

Overview

- An environmental limit is usually interpreted as the point or range of conditions beyond which there is a significant risk of abrupt irreversible, or difficult to reverse, changes to the benefits derived from natural resource systems with impacts on human well-being.[1]
- If governments do not monitor the use and degradation of natural resource systems effectively, the risks and probability of costs of such impacts on human wellbeing are not taken into account.
- If systems are to be managed within environmental limits, decisions at national, regional and local scales should reflect the implications and trade-offs for natural resource systems inherent in policy choices.
- Even where there is scientific uncertainty as to where environmental limits could be set, the risks to human well-being should be managed by policymakers.

Background

Changes in Natural Resource Systems

Human well-being is dependent upon renewable natural resources, such as agriculture's dependence upon plant productivity, soil, the water cycle, the nitrogen, sulphur and phosphorus nutrient cycles and a stable climate. An environmental limit is the boundary beyond which exploitation of a natural resource will have significant deleterious effects (Box 1, Figure 1). Natural resources include land, water, air and associated living systems that comprise the biosphere.

These can be classified into ecosystems (Box 2). Interactions between the components of ecosystems give rise to ecological processes, including 'ecosystem services' from which humans benefit (POSTnote 281), such as food, soil stabilisation, flood regulation, the chemical composition of the atmosphere and pollination (POSTnote 348). Several reports in recent years, such as the series of "The Economics of Ecosystems and Biodiversity" (TEEB) reports, have all elaborated on how impacts of a range of pressures on ecosystems, including biodiversity loss and climate change, are posing a threat to future human well-being. [2] The status of ecosystems in the UK is being analysed by the National Ecosystem Assessment (NEA), due to be published in February 2011.[3]

Some commentators do not accept the existence of environmental limits and argue that the profits from continuing economic growth could be used by future generations to reverse impacts on ecosystems, or to substitute technology for goods and services arising from the ecosystems. However, there are several economic studies showing the benefits of maintaining these services, even in the short term, such as TEEB.

Ecosystem services are fundamentally dependent on the properties of ecosystems and the biodiversity within them. All components of biodiversity, which include the number, abundance, composition, spatial distribution, genetic diversity, population structure and interactions of living organisms, and, the physical habitats in which they are found, play a role in these interactions.[4] They influence, and in turn are influenced by, biogeochemical processes, such as the water cycle, over different temporal and spatial scales. This flow of services includes acting as a source of materials, including production of food and fibre, a sink for wastes, regulation of air, climate and water, recreation and aesthetic and cultural values of nature.[5] Human well-being, while sometimes buffered against environmental changes by culture and technology, is dependent on the flow of ecosystem services.

Box 1: Terms Associated with Environmental Limits

Thresholds are abrupt non-linear shifts in ecosystem states, affecting the capacity of the ecosystem to sustain the delivery of ecosystem service benefits. These typically result from a combination of gradual alterations in drivers, such as land use change, that appear to have little or no apparent impact up to a certain point, until an external shock such as storm, fire or disease outbreak causes the ecosystem to shift from one set of mutually reinforcing ecological processes to another.

Environmental limits are established on the basis of the minimal acceptable output of benefits or the societal choice for the level of risk of crossing a threshold (figure 1),[6] such as the Copenhagen Accord to limit temperature rise due to climate change to two degrees Celsius above pre-industrial levels.

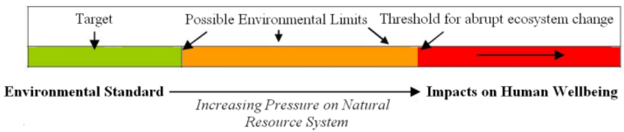
Environmental standards are generally used on a precautionary basis to inform target setting for environmental policies, such as reductions in levels of pollutants that affect human health. They include not only numerical and legally enforceable standards, but ones that are not mandatory but contained in guidelines, codes of practice or sets of criteria for deciding individual cases. They are judgements about the acceptability of environmental modifications resulting from human activities that are both:[7]

- formally stated after some consideration and intended to apply generally to a defined class of cases; and,
- in relation to sanctions, rewards or values, expected to exert a direct or indirect influence on activities that affect the environment.

Targets are used to monitor and set progress towards environmental standards. For example, the 'good ecological status' requirement set under the EU Water Framework Directive is based on compliance with more than 50 objectives, on a water-body specific basis (rivers, lakes, canals, estuaries, coastal waters and ground waters) relating to biological, chemical and physical quality, including for levels of specific pollutants, such as pesticides (POSTnote 320).

Indicators for monitoring ecosystem services are an essential tool for measuring the success of policies or negative trends that need addressing (Box 4). The driving force-pressure-state-impact-response (DSPIR) framework is a commonly used approach to structure and analyse environmental indicators (POSTnote 312).

Figure 1: The Relationship between Targets, Standards and Environmental Limits.[1]



Thresholds in Ecosystems

The potential for the delivery of ecosystem service benefits from natural resource systems depends on ecosystems being in specific states. These can change once biological and physical ('biophysical') boundaries are exceeded, affecting the capacity of the ecosystem to sustain the delivery of benefits. Threshold shifts typically result from a combination of drivers of environmental change that gradually reduce the resilience of natural resource systems and external shocks that can rapidly push the stressed ecosystem into an alternate state. The system shifts from one set of mutually reinforcing interactions to another, creating significant obstacles to reversing such changes. The resilience of ecosystems to external shocks, and the reversibility of shifts, is dependent on many factors, but loss of biodiversity appears to be a critical one.[4, 8,9]

Box 2 Ecosystems

The Convention on Biological Diversity (CBD) and Millennium Ecosystem Assessment (MA) defined ecosystems as: "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit". The key feature of ecosystems is that they are fully integrated systems, with 'emergent properties' arising from interactions between the living and non-living elements of which they are composed. Indicators of the boundaries of ecosystems are often defined in terms of the status of their dominant vegetation or environmental features, such as grassland or a lake, but are essentially a construct defined according to the scale of human interests and decision-making abilities. They can be defined as areas which share similar environmental features in terms of:

- climatic conditions;
- geophysical conditions;
- dominant use by humans;
- surface cover (based on type of vegetative cover in terrestrial ecosystems or on fresh water, brackish water, or salt water in aquatic ecosystems);
- species composition; and,
- resource management systems and institutions (such as marine fisheries).

They usually have strong interactions among their components with weaker interactions occurring across the boundary of the systems. For example, the interactions between organisms in a lake are generally stronger than those between the lake organisms and those on surrounding land. Nonetheless, ecosystems do have fluid boundaries. In the case of lakes, species such as toads, frogs and dragonflies will move between water and land in their life cycle, and there are also flows of water and minerals between land and water. As such, ecosystems are just one set of interactions nested within wider sets of interactions up to the global scale (and interactions with physical conditions beyond even this, such as solar radiation).

Examples of abrupt irreversible threshold shifts are limited, although well documented in freshwater ecosystems, marine fisheries and drylands, such as grassland savannahs. For example, in Lake Veluwe in the Netherlands, in the late 1960s and early 1970s, the ecological condition of the lake hardly changed in response to increased nutrient levels until a threshold was reached. Beyond this point, the water plants that had dominated the lake (charophytes) died off and turbid water conditions became established (eutrophication). The ecological condition was not restored until the nutrient levels were reduced far below the threshold level at which the change occurred (hysteresis). Eutrophication in freshwaters can be irreversible, or reversible only after massive reductions of phosphorus inputs for decades or longer, owing to the internal cycling of phosphorus within the lake system and the accumulation of phosphorus in the soils of the catchment area, which will leach into the lake over time.[10]

Limits and Thresholds

Such shifts pose a substantial challenge to the management of natural resource systems. Unlike limits, which are to some degree a matter of societal choice (Box 1), thresholds are an inherent property of ecosystems. However, these shifts are difficult to predict, due to limited understanding of how ecosystem processes and organisms respond to environmental change.[11] Modelling systems is difficult as ecosystems may show little change before the threshold is exceeded.[8] For many ecosystems, the only way thresholds can be identified is when they have been crossed and a regime shift to a different ecosystem state occurs.[9] Although there are varying degrees of uncertainty about where thresholds lie, it is possible to manage the risks of shifts by reducing pressures on ecosystems, for example, by enhancing and maintaining biodiversity.

Scientific uncertainty about thresholds, and the consequence of exceeding them, may result in a lack of political consensus about where environmental limits should be set. Defining limits requires understanding of the social and economic impacts arising from environmental degradation, a means of mitigating or reducing drivers/pressures of environmental change and a legislative framework within which they can be addressed, such as the Climate Change Act.

A recent Government Economic Service review of the Economics of Sustainable Development stated the importance of the government sending clear signals to business about existing statutory environmental *limits*, as an essential part of developing an environmentally sustainable economy.[12] As well as thresholds, several other terms are closely associated with the concept of environmental limits, including environmental standards, targets and indicators (Box 1). There is confusion in the use of these terms, and Defra intends to publish a summary list of all existing UK statutory environmental limits to ensure that ministers are advised appropriately when policy proposals "jeopardise" an environmental limit, such as air quality standards.

Accounting for Natural resources

Global environmental depletion and degradation, costs about 6% of world GDP annually, or $3 trillion in 2006. Natural resource depletion accounts for 89% of this, with the remaining 11% being greenhouse gas emissions and other air pollutants.[5] By adopting its new biodiversity loss target, the EU has recognised the undervaluation of ecosystem services as a cause of natural resource depletion and considers it essential to integrate their correct valuation into the UN System of Standard National Accounts to reflect the depletion and degradation of environmental assets and functions.[13] The need for national economies to reduce their environmental impact was also recognised, to '*keep human activity within safe ecological limits and to avoid human-induced loss of biodiversity through extinctions and passing other ecological points of no return'.*

Resource functions, (the supply of raw materials from the environment), are generally traded as market goods and are already in national accounts. The use of or impact on ecosystems, such as disposal of pollutants by release into the environment, are not freely marketed and are not straightforward to incorporate into national accounts. For example, the UK is dependent on ecosystems in developing countries for the supply of agricultural commodities, such as palm oil, whose production can have environmental impacts, such as land use change and biodiversity loss that are not effectively accounted for. If environmental limits in countries that supply such benefits are exceeded, the cost of commodities will increase, affecting food security in the UK and globally. An understanding of how to maintain ecosystem service benefits at acceptable levels, and the reinvestment required to achieve this, provide a way in which the notion of environmental limits could be incorporated into environmental accounting.

Critical Natural Capital

The term 'capital' is used to describe a stock or resource that produces revenue or yield. Natural capital is usually interpreted as an economic metaphor for environmental assets, such as forests, soils or marine habitats that supply resources to the economy or offer a receptacle for disposal of wastes (Box 3). 'Critical Natural Capital' refers to the level of unexploited natural assets required to ensure that ecosystems maintain the flow of beneficial services vital for human well-being at acceptable levels.

Box 3 Natural Capital

Natural capital differs from other types of capital in that it can be degraded beyond critical thresholds affecting the flows of beneficial services to people, for example, decreased crop yields from degraded soils. Four basic categories of natural capital are generally recognised: air, water (fresh, groundwater and marine), land (including soil, space and landscape) and habitats (including the ecosystems, flora and fauna which they both comprise and support).[14] The quantity and the quality of natural capital affects the quantity and quality of benefits generated. For example, the recreational, amenity and other services enjoyed by a population living around a stretch of any river are reduced, if the quantity of water diminishes significantly and/or if water quality deteriorates. The use and flow of benefits from natural capital also vary spatially, so it also matters *where* natural capital assets are maintained or protected.

For example, wetlands can absorb and slow flood pulses within a river catchment as well as maintaining river flows during periods of low rainfall (POSTnote 320). Wetlands provide benefits for the largest numbers of humans if located in areas from which these benefits flow to large conurbations. If the wetlands were drained, these benefits would have to be supplied by building dams, levees and reservoirs, and each of these engineered solutions could have negative impacts on other ecosystem services.

There are numerous different stable ecosystem states possible for a given location, giving rise to different combinations of ecosystem services, with changes between states resulting in losses or gains of different benefits. Consumers of benefits are likely to vary geographically, socially and economically, with increased consumption of one service by one group having implications for the delivery of other services to other groups. Current changes in natural assets, such as biodiversity loss, also have implications for future consumers of benefits.[15]

Natural capital accounts could be used in the same way as economic accounts are used to measure economic activity. This would require identifying the different stocks of ecosystems, for example, habitat types, the pressures that affect them and the consequences for the flow of ecosystem service benefits. This can be done through representing the quantity and quality of natural capital stocks in physical units and through monetary valuation of the flow of benefits. However, given the scientific uncertainty in relation to thresholds (Box 1), it is likely to be difficult to agree environmental limits for exploitation of some natural resources.

The Ecosystem Approach

The ecosystem approach makes explicit the link between the status of natural resource systems and social well-being. The UN Convention on Biological Diversity describes an ecosystems approach as “a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way”. Principle 6 of the ecosystem approach explicitly states that management of ecosystems should take a cautious approach “to the environmental conditions that limit natural productivity, ecosystem structure, functioning and diversity”.

The establishment of environmental limits is complementary to other aspects of implementing the ecosystem approach. It requires that policies should reflect that the impacts of human activities are integral to ecosystem interactions, just as ecosystems are integral to human activities, and that the processes underlying ecosystem services are inherently complex and dynamic at many temporal and spatial scales.[16]

Although impact assessment of new UK policies, programmes and projects already requires environmental impacts to be assessed,[17] the methodologies used do not effectively take account of the costs associated with impacts on ecosystems and the benefits arising from better management of ecosystems. In December 2007, Defra published *Securing a healthy natural environment: An action plan for embedding an ecosystems approach*. This was updated in the 2010 *Delivering a healthy natural environment*. Guidance on how environmental values and ecosystem services should be taken into account in policy decisions will be published shortly.[16] Supplementary guidance to the Treasury’s Green Book on accounting for environmental impacts in policy and project appraisal will also be published, including new specific impact tests for ‘wider environmental impacts’ and ‘sustainable development’.

Maintaining Provision of Ecosystem Services

The ecosystem approach requires policy makers, landowners and other stakeholders to work together to achieve commonly-agreed ecosystem goals in a given locality. This could cause conflicts over the trading-off of private gains against wider public benefits arising from changes to ecosystems. Where there is uncertainty, this may result in the policy process to establish environmental limits faltering. Different stakeholder groups could use the existence of uncertainty as a rationale for arguing for levels of natural resource use that favours their interests. Scientific evidence on thresholds and the consequences of exceeding them may be disputed in these circumstances, the validity of research findings.[18]

However, the risk of environmental changes impacting human well-being raises significant governance issues. If governance mechanisms are to maintain general human well-being, they will have to ensure that levels of use of natural capital are in balance with the conservation of natural resource systems. This may require valuing the needs of the whole natural resource system over the vulnerabilities of specific social groups. Decision making strategies should consider a range of plausible alternative outcomes to accommodate uncertainty,[19] to identify management strategies for natural resource systems that are sufficiently robust across all likely futures (Box 4).

Scenarios will be used in the UK NEA to determine how UK ecosystems and their benefits might change up to 2050.[20]

Box 4 Incorporating Environmental Limits

With environmental limits, the critical variable is the output of benefits from ecosystems. To determine these requires the provision of adequate baseline information on natural resource systems and related ecosystem services, the environmental state of the system, the pressures acting on it, the benefits it provides, the relationship between pressures, states and levels of benefit provision and the subsequent system interactions. Plausible scenarios, based on the impacts of direct and indirect drivers of ecosystem changes on ecosystem service provision, would then be a first step in limit and target setting against relevant indicators.[20] The general process for establishing environmental limits can be summarised as[21]:

- establish the range of benefits provided by the natural resource systems, the potential for the provision of multiple benefits and trade-offs between those benefits under different policy options
- establish an evidence base – a suite of indicators to monitor the delivery of benefits from the natural resource system against environmental limits set, including evidence of biophysical thresholds. (Indicators for ecosystem service provision are still being developed and will require a better understanding of how sensitive ecosystem service provision is to environmental change);
- set environmental limits beyond which the level benefit provision becomes unacceptable, on the basis of scientific evidence, expert judgement and societal considerations. Where there is scientific uncertainty, the level of risk that communities are willing to incur becomes more critical; and,
- implement management measures to ensure flows of benefit provision are maintained within environmental limits. The extent of management measures implemented should reflect either the economic value gained from maintaining benefit provision within environmental limits or the resilience of the natural resource system in question. (Ensuring the resilience of ecosystem service benefit provision will require precautionary limits to be set given the uncertainties in the understanding of ecological processes).

Endnotes

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POST is grateful to all contributors and reviewers (listed in POST Report 370). For further information on this subject, please contact the author, Dr Jonathan Wentworth.