Sites of Special Scientific Interest (SSSI) Economics

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Sites of Special Scientific Interest (SSSI) Economics

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Foreword

Natural England regularly commissions a range of reports from external contractors to provide evidence and advice to assist in delivering its duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

1. Introduction

This think piece has been developed by eftec in association with Prof Nick Hanley to inform Natural England's future management of protected areas (PAs). It aims to address the question:

If we were arranging for the protection and conservation of important habitats, species and geological features in 2021 from scratch, what should we create in the face of environmental change?

This headline question is expanded into three sub-questions:

1. *What is required to protect biodiversity and geodiversity across the landscape in the face of climate change?*
2. *How would multiple interests including the nature recovery networks, natural capital, ecosystem services, socio-economic interests (farming, heritage, landscape, access) be accommodated?*
3. *How should we assess what 'good' and 'harm' looks like e.g. ecosystem natural function?*

This think piece answers these questions by applying environmental economics thinking. It first considers the scope of the work (remainder of this Section), and then discusses the relevance of economics to designating protected areas (Section 2). Economics thinking is applied in Section 3, and conclusions drawn in Section 4.

1.1 Scope of thinking

PAs are one of the key tools for biodiversity and geodiversity conservation worldwide. However, in the UK, the network of PAs is currently facing a number of new challenges. Firstly, with the UK exit from the EU, its nature conservation actions will revert to relying on domestic legislation. Secondly, nature conservation strategies need to adapt as climate change risks affecting weather patterns and impacts on the natural environment become more frequent and more severe. Thirdly, society's preferences change, as reflected in the 25-Year Environment Plan's anthropocentrically defined (e.g. to improve the environment for the next generation) objectives.

This think piece addresses the future design of PAs from an environmental economics perspective[1]. It is based on a context in which maintaining biodiversity (and geodiversity) is the primary reason for site identification and designation, but the scientific case for Sites

[1] In applying environmental economics concepts on the value of biodiversity, a structure of direct, indirect, resilience and insurance values is used (see Annex 1).

of Special Scientific Interest (SSSI) designation may no longer be considered persuasive enough. Environmental economics provides an additional approach to make this case, using natural capital, ecosystem services and cultural arguments.

In applying economic thinking we consider economic valuation frameworks and evidence, and their use in appraisal, rather than economics of institutions and behaviour. This perspective is particularly relevant to the latter two of the three sub-questions (above). While we recognise that economics is just one of several necessary approaches to deliberating the future of biodiversity protection, we would regard it as an essential one because it: (i) commensurably assesses the wide range of costs and benefits, and hence the trade offs involved, and (ii) provides justification for society to allocate resources to the conservation of biodiversity, both in themselves (demonstrating a positive return) and relative to other options (comparing value for money against other public policy options).

While we can consider how a PA system might be best designed ‘from scratch’, the answer to this question is influenced by the current extent, history and functions of the PA network. This is because existing PAs have cultural and scientific value as a result of their existence to date.

This history, and its values, include previous scientifically-based decisions such as why certain species are picked as the basis for designating PAs. These scientific decisions interact with economic values. The selected species may reflect, and/or can become part of, the identity of a PA, and the landscape and communities it sits in. In other cases, protected species may be scientifically significant to protect but culturally less distinctive.

The designation of PAs can be based on biological and geological features. Both can have a range of cultural and other economic values, and characteristics such as irreplaceability. However, this paper is written focussing on biodiversity outcomes and objectives.

2. Relevance of economics to PA designation

This section considers the relevance of economics to biodiversity conservation and PA designation, in the context of the current PA system, and the tools economics offers to future PA approaches.

2.1 Approach to designating PAs

To date, society has approached biodiversity from the basis of scientific conservation priorities. These priorities have sometimes been correlated with areas recognised as important for people directly (e.g. for recreation and tourism) and indirectly (e.g. in providing specific ecosystem services, such as regulation of water supplies).

PAs are defined by a spatial boundary which provides opportunities for specific legal and regulatory tools to be applied. These can implement stronger levels of protection compared to areas outside PAs. There may be different reasons for these boundaries: scientifically they help distinguish features of interest, but they also have an economic driver: the boundary of the PA limits the economic costs of the biodiversity protection to society[2]. These costs include the opportunity costs to the landowner or other potential users of the area, and to the public sector (to administer, implement / enforce and monitor the protections). Such economic costs are a limiting factor - were it not for the desire to restrict these costs, the protections for PAs could be applied to the whole of the UK (even intensively managed areas with few natural characteristics).

The current basis for defining the boundaries of PAs is scientific, and it is assumed that this will continue to be the case in future. However, the current reason for having boundaries at all is, at least, partly economic. Economics can also play a role in justifying the need for, and the design (i.e. location, extent) of the PAs network.

Scientific knowledge is constantly evolving, and recent progress has provided an understanding of how climate change is expected to impact on biodiversity. New nature conservation policies are developing in response, such as the Nature Recovery Network (NRN) which is proposed as a way to enable SSSIs to work with the wider landscape to support biodiversity and geodiversity adaptation to climate change. The need to plan for change presents a new challenge for approaches to PAs, to enable ‘adaptation by promoting ecological dynamism’. A series of priorities for resilience are relevant to the

[2] Note that the reverse is not true of economic benefits: these could be achieved through landscape-wide measures without the need for spatial boundaries as to where they apply.

NRN action plan: Buffering; Refugia; Connectivity; Prioritise the Vulnerable; and Sufficient size for natural functions (see Annex 2 for definitions).

As well as playing an (albeit indirect) role in designation of PAs, economics can also inform how to manage and incentivise activities within PA. Designation and management are not completely distinct from each other: the scientific basis of designations and spatial boundaries need to be able to be implemented in practice, and this can lead to PA boundaries or management objectives being chosen because they are a less costly and/or a more practical way of achieving management objectives, rather than for purely scientific reasons.

Therefore, economics already plays a role in PA practices, even though often implicit and secondary to science.

2.2 Using economic tools for PA designation

Giving economics a primary or explicit role in defining PAs will introduce new thinking into the process of designation.

2.2.1 Economic tools

Economics can be applied to the question of PA designation in different ways, depending on the objectives and scale of the analysis. Traditional approaches have developed based on tools for appraising outcomes at the margin:

- Assuming society wants a network of PAs, then economics would help to justify where and how large the PAs should be, as well as their level of protection and the instruments through which protection is implemented. Given an established objective, this becomes a cost-effectiveness question, with economics used to efficiently implement the objective.
- If the question is whether society wants PAs at all, then a comparison is needed between the costs and benefits they provide to society – through cost-benefit analysis (CBA). CBA can also be applied to the extent of PAs and/or the strictness of economic protections within them. CBA can be used to assess the benefits and costs from society's viewpoint of changing the boundaries of a PA, and of adding to the stock of PAs.

Economic appraisal using CBA is the default approach for public policy making in the UK, and plays a role in decisions to designate PAs (e.g. recent marine protected area designations[3]). However, applying conventional economics to the natural environment has limitations, which are reflected in recent method developments in environmental

[3] e.g. see Marine Protected Areas Designations - gov.scot (www.gov.scot)

economics, and in Government Guidance (e.g. HMT Green Book, 2020 updates and ENCA (Defra, 2020), see Section 3.1.3).

The alternative to these marginal appraisal approaches is to think about the value of the environment as an asset, as proposed by the recent Dasgupta Review (Dasgupta, 2021). This is the basis for the natural capital approach. Key features of this approach are: the distinction between stocks of assets and flows of benefits; inclusion of biotic and abiotic resources; application of scientific measurement and economic valuation approaches; identification of impacts and dependencies on the environment; and a forward-looking perspective[4].

Applying a natural capital approach frames PAs as a habitat or ecosystem asset which provides a range of benefits, as measured and valued by the extensive ecosystem services literature. However, economic analysis, while focused on expressing costs and benefits or values of stocks and flows in monetary terms, relies on scientific and other work. This science is needed for evidence to understand how costs and benefits come about; the relationship between the extent and condition of stocks and the flows of benefits they provide, and quantifying such relationships in biological or physical metrics. Given the complexities and projections of future changes, economic analysis also requires scientific assessment of risks. Such scientific analysis may not always be possible. This is particularly true in relation to climate change, which is a relatively new area of biodiversity science, where important values remain uncertain (e.g. whether biodiversity's current contribution to welfare will be maintained over time).

There are, however, simple rules of thumb that can guide the application of natural capital principles (Bateman and Mace, 2020), which are highly relevant to PA thinking. These include considering all of the major benefits and costs of a proposed change or decision, recognition of non-linearities, and that failure to consider alternative uses of resources will almost inevitably lead to poor decisions. Furthermore, the authors identify that the location or timing of change are crucial to good decision making and resource use, affecting the balance of benefits and costs (efficiency) and also their distribution across present and future society (equity), both of which are key decision criteria.

2.2.2 Limitations of economics

Economic analysis has three key limitations: (i) the need to define the relationships between changes in natural capital assets to the benefits they provide; (ii) often simplifying assumptions about the form of such relationships; and (iii) bias towards available (i.e. market) data by some economists and decision makers.

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[4] What is a Natural Capital Approach? (The Capitals Coalition – redefining value to transform decision making)

Firstly, economic analysis is based on a qualitative and quantitative assessment of how the benefits provided by natural capital changes due to the actions or decisions analysed. Uncovering such information is not always possible. We may have a general understanding of the benefits provided by an asset, but it may not be possible to measure or estimate the change in benefits due to change in asset extent or condition. This is particularly the case where we want to value the contribution of PAs to resilience. In addition, the changes must be defined against a baseline, which may be complex for PA designation, as this counterfactual may involve displacement of land use activities or other unanticipated long-term effects. The natural capital approach may make a simplifying assumption of a 'no-asset' baseline, allowing it to value the whole asset. However, this does not remove the baseline or non-linearities problems. Economics tools are capable of being adjusted to account for such 'dynamic' baselines and non-linearities, but this requires data quantifying these effects, which may not be available due to the limitations of the underpinning science.

Secondly, and not surprisingly, nature does not behave according to the simplifying assumption of linear changes across space and time. For example, crossing thresholds in environmental effects, such as through habitat fragmentation, could lead to collapse of a species population. For biodiversity, the dynamic objectives of the NRN introduce further non-linearities: the size and refugia objectives create potential for increasing returns to scale for additional areas protected and/or managed for biodiversity

Finally, inclusion of resilience in economic analysis is a challenge, which is important for biodiversity, as greater biological diversity is often associated with greater resilience (Dasgupta Review, 2021). It is not always possible to quantify the benefits of resilience – or reduced variation in values. Resilience as a benefit is generally not traded in markets (although some insurance markets exist), and there is limited evidence on the role of PAs in ensuring that benefits are sustained over time.

The following approaches can be used to counteract these limitations, especially where risks are significant and negative impacts are non-linear:

- Distinguishing 'Critical Natural Capital[5] Assets'. This can be applied to PAs, where they protect assets that cannot be found elsewhere or at least not in that extent or condition; or where they produce particular services that cannot be provided elsewhere, and
- Applying the precautionary principle. This is also relevant to PAs, which may be preventing potentially irreversible losses of ecosystems and/or benefits from biodiversity.

[5] That part of the natural environment, which performs important and irreplaceable functions (Chiesura & de Groot 2003).

Both these approaches integrate economic and scientific thinking to generate arguments for PA designation. What is viewed as critical or irreversible is based on science, but expressed using economics to show the consequences of decision.

2.2.3 Introducing economics in PA designations

Explicitly applying economics to PA designations would be a major change: moving beyond using only ecological criteria which, to date, have explicitly excluded economics as a designation criteria[6]. Including economics thinking is a significant change because it would:

- Introduce instrumental values of nature into considering protected areas network design;
- Need to determine whose values, in particular which groups in society and over what timescales, would be considered;
- Need to deal with uncertainty in understanding of some benefits and costs. For benefits, there are challenges in how we deal with partial information of the different benefits from biodiversity (see Annex 1). Several important dependencies of human wellbeing on biodiversity remain poorly quantified and valued for decision-making. For example, we know nature (but not particularly PAs) is good for people's mental wellbeing, but cannot consistently reflect that value in economic decision-making.

A further dimension to using economics in biodiversity and PA policies is in how it will influence the communication of PA policy. Science can identify what is important for nature conservation, and identify the benefits of preserving nature and its functions. However, economics introduces further tools to help explain why certain factors are prioritised, why PAs are a preferred solution for achieving biodiversity objectives, or why certain species are selected as representative of ecosystem condition. This can be viewed as both a positive (widening the ability to communicate to different audiences), or a negative (diluting the scientific message).

A combination of science and economics can illustrate dependencies on the natural environment of human wellbeing. Introducing economic methods can help to develop different perspectives on PA management. They are not only useful to give an 'economic' answer in the sense of a monetary value or socio-economic data, but can help frame scientific research and evidence in a way that is easier to integrate into policy and financial decision making.

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[6] For example, the European Commission Birds and Habitats Directives prohibit defining site boundaries based on economic criteria.

3.Applying economic thinking

This Section applies economic concepts to the analysis of biodiversity and PAs, considering limitations and illustrating the insights economics can provide.

3.1.1 Conceptual framework

How to apply economic thinking to biodiversity has long been a challenge – not only because of the complexity of natural systems, but also the multifaceted ways humans interact with nature and diversity within it: Biodiversity is a critical aspect of the functioning of natural capital assets, a benefit people can value for its direct use, existence, and plays a role in the generation of other benefits. Annex 1 illustrates a classification of the variety of different types of direct and indirect contributions of biodiversity to wellbeing.

These different values can all apply to PAs. Table 1 shows how PA designation could contribute to wellbeing, using the classification from Annex 1. The impacts are assessed relative to a baseline of typical commercial land use in England, such as agriculture.

Table 1: Relevance of contributions of biodiversity to wellbeing to PAs

	Direct Contribution to welfare	Indirect contribution to welfare		
Use value	*Direct benefits to households*	*Relationships between ecosystem services and production of final goods and services.*		Resilience value (s)- dependency on biodiversity for sustained ecological functions and process that underpin all contributions to welfare. **PAs: maintained or enhanced**
Consumptive use	Provisioning services: e.g., wild food. **PAs: restricted**	Provisioning services: e.g., timber, food. **PAs: restricted**	Insurance value(s): reduced variation in future income. **PAs: enhanced**	
Non-consumptive use	Cultural services: e.g., wildlife-based recreation, aesthetics and amenity,	Regulating services: e.g., carbon storage and sequestration, air quality		

	physical and mental health. **PAs: restricted or enhanced**	regulation, flood regulation. **PAs: maintained or enhanced**		
Option value	Future consumptive and non-consumptive use values			
	PAs: maintained or enhanced			
Non-use value	Direct benefits to households			
Altruism, bequest, and existence value motivations	Biodiversity conservation (e.g., threatened or priority species) **PAs: maintained or enhanced**			

The expected impacts of PAs on the contribution of biodiversity to wellbeing, varies:

- PAs are likely to restrict direct or indirect consumptive uses dependent on aspects of biodiversity (that is, PAs may reduce the supply of provisioning services).
- PAs may restrict or enhance direct non-consumptive uses dependent on aspects of biodiversity (cultural services). The effect will depend on the specific cultural activity/benefit. For example, PAs can maintain the quality of ecosystems as a recreational resource, but can restrict recreational access or types of recreational activity to avoid disturbance.
- PAs will usually enhance, or at least maintain, indirect non-consumptive uses dependent on aspects of biodiversity (regulating services).
- PAs will generally maintain or enhance the contribution from aspects of biodiversity which are relevant to:
    - Option values of consumptive and non-consumptive uses,
    - Non-use values (including most obviously for the existence of biodiversity – the reason PAs are scientifically defined); whilst:

- PAs can increase the resilience of economic value flows to future disturbance, shocks and change. For example, they can reduce the future variation in benefits from those uses (insurance value), and may increase values of these uses in adjacent areas in specific circumstances (e.g. through marine protected areas spill-over effects or by maintaining pollination services).

Thus, PAs can have a combination of positive and negative effects on the different contributions of biodiversity to wellbeing. The net effect of these changes is uncertain, and the aggregate impact can be net positive or negative to different individuals, households, communities, or generations. Furthermore, the ability to measure and value the contribution of biodiversity to these effects in economic analysis varies, often being embedded in other inputs and difficult to separate.

The contributions of PAs that are related to market activities (e.g. provisioning services) are more likely to be readily valued in monetary terms. The contributions for which there are no market effects can be harder to value, but a range of methods are available to generate value evidence. These have been successfully used to value aspects of biodiversity in the UK (e.g. See 3.1.2), but only in a small number of studies, resulting in a limited evidence base for some contributions of biodiversity to wellbeing.

The distribution and characteristics of effects identified in Table 1 has implications for how PA designation will be assessed in economic analysis:

1. The scope of economic analysis always has a significant impact on its conclusions. This could be even more significant here due to the variation of type and scale of impacts of PAs. Scope and its effects will apply geographically, socially (in relation to which affected groups are considered); or over time (including inter-generational effects).
2. The restrictions to consumptive use benefits are likely to bias analysis, as these benefits are more likely to be quantified and have monetary values from market data, resulting in them being included more often and with greater confidence in (market) economic analysis.
3. Most of the benefits are likely to be non-linear due to a variety of factors:
    (a) They may show diminishing marginal effects (meaning benefit per unit of protection decreases as protection increases).
    (b) Increasing returns to scale through factors such as connectivity and refugia identified for the NRN.
    (c) The insurance / resilience values may show increasing returns to scale and/or non-linear increases, particularly if implementing the size and connectedness objectives of the NRN.
    (d) Related to this, if PAs mean that thresholds are not crossed, they may help maintain wellbeing at a higher level that can be sustained in the long term.
4. The benefits of resilience to all the values identified is significant in the context of climate change.

The combination of these factors means that economic analysis of PAs will be inconsistent and subject to capture if it does not strictly follow the natural capital analysis rules set by Bateman and Mace (2020) of considering all of the major benefits and costs of a proposed change decision, and recognition of non-linearities and distributional issues. Even with these rules, there is still a risk of bias that the positive effects of PAs on the contributions of biodiversity to wellbeing (ii and iv), and its role in resilience (under iii) are generally those that are harder to measure and value.

Where the contribution from biodiversity to welfare can be measured and valued, it will be integrated into CBA or natural capital accounts as a discounted flow of benefits. This involves application of a discount rate to weight future impacts lower than current impacts. One of the justifications for discounting is expected higher future wealth, and therefore different consumption choices (substitutes). However, economic appraisal guidance recognises that some aspects of welfare (e.g. human health) have no substitute, and therefore discounts them less. Biodiversity also arguably has similar nonsubstitutability characteristics, and this has implications for suitable discount rates. The same argument for a lower discount rate also applies to actions that will increase future resilience.

Non-substitutability can also be a characteristic of habitats or ecosystems, leading to the concept of critical natural capital assets (see above).

3.1.2 Economic evidence

There are a range of methods with which to value the non-market contributions of biodiversity, and these can be applied to PAs. Such research has been undertaken successfully in the UK and elsewhere (see Box 1). Economic analysis can cover many of the benefits of PAs, but the evidence base is incomplete, and its application in decision-making remains inconsistent.

The dominant values expected in economic analysis of protected areas are:

- Society's preference to conserve biodiversity, for both known and poorly known species (this can be motivated by use/non-use, direct/indirect values for altruistic, bequest or existence reasons;
- The role of provisioning services in the livelihoods of local communities;
- The welfare value (and possibly associated tourism and leisure impacts) from access to outdoor recreation, and
- Values of key regulating services, such as sequestration and storage of Green House Gases.

It should be noted that some aspects of value in the framework shown in Table 1 are poorly covered in the literature. For example, the case was made for designations as a tool for maintaining diversity and overall resilience, even if marginal is evidence lacking, in the Benyon Review of Highly Protected Marine Areas (undated). One of limited number of studies on resilience is Worm et al (2006), which found that overall, rates of resource collapse increased and recovery potential, stability, and water quality decreased exponentially with declining marine biodiversity. They conclude that marine biodiversity loss is increasingly impairing the ocean's capacity to provide ecosystem services and recover from damage.

Conservation investments rely heavily on public funding and hence, on public support, but little of the valuation literature examines potential future PA strategies. Lundhede et al's results suggest that cross-country coordination of conservation efforts under climate change will be challenging. Both in terms of achieving an appropriate balance between cost-effectiveness in adaptation and the concerns of a general public - who seem mostly worried about protecting currently native species.

There are no studies (that we are aware of) in the UK examining the value of non-PA habitats in PA connectivity. The relationship between PAs and surrounding land uses, in particular farming, should be subject to further research. The connection to farming is particularly pertinent given the 'public goods' objective of the forthcoming Environmental Land Management Scheme (ELMs). These economic criteria, in the design of environmental payments, which are a major source of funding for SSSI management, are another example of how economics already influences PA management.

Box 1: Economic research on the value of biodiversity and Protected Areas

There is a limited evidence base on the economic value of biodiversity and protected areas in the UK. Relevant terrestrial PA studies include Jacobs et al (2004) which established positive Willingness to Pay (WTP) for Scottish Natural sites, and Christie et al (2012) values for SSSIs. The latter identified WTP for different ecosystem services to different SSSI habitats, based on ranking of those habitats for the services by expert judgement. Values vary by a factor of 3 or more between habitats.

Potentially relevant to PA management, Christie et al (2006) valued conserving local familiar/unfamiliar and/or rare/common wildlife species on farmland. However, this requires interpretation in the context of connectivity objectives and expected impacts of climate change. Studies relating to biodiversity more generally (not only in PAs) include a range of studies relating to habitats. Most focus on direct contribution to welfare in terms of non-use values, for example on forest biodiversity (eftec 2019), and agri-environment evidence (e.g. eftec, 2006; Boatman and Willis, 2010).

There are also some economic valuation studies on marine protected areas, motivated by the ongoing designation process in the UK marine environment. McVittie and Moran (2008) and Kenter et al (2013) both assess the impacts of marine conservation measures, such as the designation and implementation of management measures in protected areas. McVittie and Moran (2008) valued a network of Marine Protected Areas (MPAs). It identified significant value to households across the UK for a network that would 'halt marine biodiversity loss', but it is not clear that this outcome is a realistic impact of MPAs, illustrating the difficulty of formulating policy-relevant valuation studies from limited scientific knowledge.

Kenter et al (2013) identified a reduced risk of damage as motivating WTP for proposed marine protected areas in Scottish Waters. They valued different management scenarios, identifying increased values for moving from designation only, to also implementing management measures. Where valuation studies cover biodiversity/PAs that are remote and unlikely to be visited by survey respondents, this can be interpreted as providing evidence of non-use values. For example, a study by Jobstvogt, et al (2014), identified that Scottish households had positive values for conserving deep water corals, which most people are never likely to see and only benefit indirectly from their ecosystem services.

There is further literature from outside the UK, particularly in the USA. In Europe, a study investigating policy choices for climate change and biodiversity by Lundhede et al (2014) found that Danish citizens are willing to pay much more for the conservation of birds currently native to Denmark, than for bird species moving into the country – even when they are informed about the potential range of shifts associated with climate change. The only exception is when immigrating species populations are under pressure at European level. Furthermore, people believing climate change to be man-made and people more knowledgeable about birds tended to have higher willingness to pay for conservation of native species, relative to other people, whereas their preferences for conserving immigrant species generally resembled those of other people.

3.2 Implications for PAs

This section applies the discussion in preceding sections to consider how an economics perspective would shape the design of PA networks, and their management.

3.2.1 PA Networks

The expected impacts of PAs on the different contributions of biodiversity to wellbeing, noted in Table 1, are listed in Table 2. The table looks at how consideration of each of these values would contribute to developing a National PA designation and management strategy, subject to the scientific reasons and requirements for PA designation (i.e. containing habitats of higher biodiversity value and/or those capable of being restored to such a state).

Table 2 shows that, depending on which values are maximised, and considering different aspects of biodiversity’s contribution to human welfare, will lead to very different PA strategies. Notwithstanding the many influences on current patterns of PAs, it can be argued that the need for designations is mainly driven by opportunity costs. Opportunity costs, in turn, are driven by what consumptive use the land can be put in and hence what market values it can generate. As a result, PAs in England protect more extensive areas in the uplands (which have lower opportunity costs) and smaller areas of some lowland habitats[7] (where some habitats, like freshwater wetlands, have suffered extensive loss[8]), and which are typically on land with higher opportunity costs of protection.

It should be noted that the correlation with opportunity costs does not mean it is a driver of designations. The causality may be in the opposite direction: that land with more productivity in terms of market outputs (and higher opportunity costs) is more likely to have been subject to intensive commercial uses that damage biodiversity, making the land unsuitable for designation based on the relevant criteria at the time (of preserving the best representative biological communities).

A PA strategy that prioritised different types of benefits to people would be less strongly influenced by opportunity costs. Longer term values of altruism and resilience, and option values, would try to maximise the full range of benefits provided. For most non-consumptive uses, priority PA locations would be those that maximise benefits to people by being close to them: this is the case for recreation, and regulation of air quality. Location is also important to benefit from regulation of hydrology (flood, drought, water quality), but this is driven by catchments, aquifers and supply networks rather than proximity as such.

A further dimension of the PA strategies in Table 2 is the influence of climate change. This is potentially relevant to all types of welfare contributions. For consumptive use values, the opportunity costs of land may alter due to climate change. For example, climate change will reduce the opportunity costs of designating land with increasing risk of flooding, drought or other risks. However, if standard economic approaches to discounting are used (as per HMT Green Book 2020), the weight put on these future changes will be very low.

Climate change will have a greater influence on contributions to welfare that explicitly put greater weight on future values (i.e. option values; altruism, bequest and existence values; insurance; and resilience value motivations). These will need to consider risks that climate change creates for PA designation decisions, including:

- Making the wrong decision that 'locks-in' a certain approach to biodiversity conservation, which is difficult to reverse. For example, conserving freshwater habitats in coastal areas where they are vulnerable to saltwater flooding/groundwater intrusion, or designating insufficient space to provide a buffer that would enable habitats to adapt.

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[7] For example, open upland habitats such as heathlands accounts for 16% of priority habitat (PHI) in England, but 21% of the SSSI network; but deciduous woodland accounts for 39% of priority habitat (PHI) in England, and 6% of the SSSI network. Sources: Priority Habitats: 2a. Status of threatened habitats (**Error! Hyperlink reference not valid.**); SSSI areas: Christie & Rayment (2012)

[8] The UK has lost 90% of our wetland habitats in the last 100 years. Water | The Wildlife Trusts

- Changing the relative abundance/vulnerability of species, and therefore their priority in the selection of species and thus sites, for designation and for management priorities.
- Having insufficient connectivity between PAs, restricting movement of species across the landscape.

As a result, additional climate change adaptation strategies are needed for these values, using buffers and connectivity to increase the ability of PA networks to support these contributions to welfare in the future.

Table 2: Influence of Biodiversity's Contribution to Welfare on PA Strategies

Contribution to welfare	**Impacts of PAs on that contribution**	**National Protected Areas Strategy to Maximise Value from that Contribution**	
		Site selection	Site management
Direct (direct benefits to households)			
Use value			
Consumptive use	Restrict	Minimise opportunity costs of sites	Maximise consumptive uses that are allowed within the designation
Non-consumptive use	Restrict or enhance	Have greatest accessibility[i] and close to the greatest number of people	Enable access through facilities which absorb visitors while minimising disturbance
Option value	Maintain or enhance	Maximise total current (or, if known, future) economic value – likely a range of habitats	Maintain total current (or, if known, future) economic value – likely a range of habitats
Non-use value			
Altruism, bequest and existence value motivations	Maintain or enhance	Scientifically determined to protect best existing biodiversity, and restore and connect biodiversity to improve its future resilience	Scientifically determined to maintain best existing biodiversity, and restore and connect biodiversity to improve its future resilience

		(Within these constraints, may minimise costs & opportunity costs).	
Indirect (Relationships between ecosystem services and production of final goods & services)			
Use value	Restrict	Minimise opportunity costs of sites	Maximise production for consumptive uses that are allowed within the designation
Non-consumptive use	Maintain or enhance	Are close to the greatest numbers of people through proximity [ii]	Manage for a range of ecosystem services, not just biodiversity
Option value	Maintain or enhance	Maximise total current (or future if known) economic value – likely a range of habitats, with connectivity	Maintain total current (or future if known) economic value – likely a range of habitats, and their connectivity
Insurance (of consumptive uses)	Enhanced	Maximise coverage of features that support future consumption	Minimise opportunity costs while ensuring consumption does not damage asset and put future consumption at risk
Resilience (of use and non-use value)	Maintain or enhance	Scientifically determined to protect critical natural assets, and restore and connect assets so that benefits have future resilience.	Scientifically determined to protect critical natural assets, and restore and connect assets so that benefits have future resilience.

Key: Use buffers and connectivity to adapt to climate change

Notes: [i] not all habitats are equally accessible to people. [ii] except for Carbon, for which value is a-spatial

3.2.2 PA Management

A further question that economics can help answer, and which interacts with questions of PA designations, is ‘what is the best way of influencing the behaviour of land-owners within a PA network?’ This question is subject to an extensive economics evidence base on the subject of Payments for Ecosystem Services (PES)[9] design. This question is important in England because the majority of land, and the majority of land in PAs, is private land.

A key feature of this evidence is the efficiency of paying for benefits, rather than paying landowners to avoid damage. This represents a significant shift in property rights. Paying to avoid damage implies landowners have a right to damage biodiversity, and therefore should be compensated for not doing so. This translates into the current opportunity-costs based system of rates for agricultural payments (including the higher-level scheme which supports the management of many SSSIs). Payments to avoid damage are flawed because the payer (Government) faces information asymmetry, with the payee (landowner) knowing more about the real level of threat to the biodiversity (see Annex 3). It is also against the Polluter Pays Principle.

In contrast payments can be designed as incentives to support delivery of benefits for biodiversity and PAs. This requires evidence of which benefits are provided, which to prioritise and where. Economics can help answer this challenge in different ways: firstly in identifying where the benefits from biodiversity[10] are greatest to prioritise payments, secondly to identify the level and distribution of costs to landowners of changes in PA designation and/or management, and thirdly on likely behavioural responses from these landowners to inform payment design.

Priorities for payments now include the new requirements introduced by climate change. Given the current and future likely impacts of climate change on biodiversity, species will often need to move in order to survive. Therefore, society has a need to allow species to move through the landscape, and ways to incentivise this connectivity are considered in the PES design literature on spatial coordination. This means that the idea of a set of isolated PAs which can be maintained in some fixed condition and thus continue to support some fixed plant or animal population is misleading (Thomas et al, 2015). To achieve a goal of species conservation, a spatially-connected network of SSSIs is needed, so that each SSSI is connected to others via corridors of land managed for conservation within other land uses (i.e. beyond the PAs) – primarily on farmland as this in the dominant land use in England. Agri-environment schemes which reward participation by neighbouring groups of farmers (joint rather than single participation) could produce this kind of spatial coordination (Banerjee et al, 2021).

The Nature Recovery Network framework sets out one such connected network. However, current agri-environmental schemes are poorly designed to deliver this kind of spatial

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[9] Defined as a voluntary transaction between a service buyer and service seller that takes place on the condition that either a specific ecosystem service is provided or land is used in a way to secure that service. (Wunder, 2005).

[10] These are not limited to use values and where beneficiaries are.

coordination, since they do not reward farmers (on the whole) for joint conservation actions with their neighbours. Economic incentives exist which can generate spatial coordination in enrolment of private land in conservation management: the agglomeration bonus (Parkhurst et al, 2003) is a 2-part payment scheme. A first (uniform) participation payment is offered to all who enrol in the conservation scheme, switching land management to a regime designed to increase some metric of biodiversity or environmental quality. A second bonus is paid to all who enrol if at least one of their neighbours also enrolled. This creates a “coordination game”, since the payoffs to each landowner of enrolling now depend partly on what action their neighbours take. Lab and field experiments show that the agglomeration bonus can create a variety of spatial coordination patterns (e.g. wildlife corridor; large area of contiguous enrolled land; riparian buffer strips).

A similar approach, more focussed on PAs, would be to incentivise connectivity to a PA. This could be done for those directly adjoining a PA (i.e. incentivising buffers to PAs), or also extending to land managers connected to a PA via one or more adjoining land owners (incentivising buffers and wider connectivity). Apart from the latter making larger areas of land available, it is not clear exactly how the outcomes of such incentives might differ, and real-world pilots of these incentives (in addition to the evidence generated by socio-economic ‘lab experiments’) are required.

Another mechanism which can generate spatial coordination is to use an environmental benefits index in a conservation auction which gives higher scores to bids from neighbouring farms. This has been shown to be capable of generating corridors of conserved native vegetation in the Southern Desert Uplands (Queensland, Australia), for example (Windle et al, 2009; Banerjee et al, 2021).

ELMS design

Using positive payments to landowners on whose land SSSIs are located would change landowners perceptions of SSSI stewardship as a benefit rather than a cost, since they would be paid for increasing ecological quality in the SSSI above some baseline condition. This approach may be possible within the new rules being devised for ELMS. The economic incentives which can create spatial coordination in conservation land use are relevant for the buffering and connectivity goals of the NRN.

This has implications for how the development of ELMS could be steered to benefit the enhancement of the SSSI network. Consider a private landowner on whose property a SSSI is situated, and which is surrounded by landscape consisting of a number of farms. The owners of these farms can participate in agri-environmental schemes such as ELMS. Ecological quality at the SSSI would be enhanced if:

- **I.** those patches of farmland which are directly adjacent to the SSSI adopted a conservation land management practice, so that the SSSI is surrounded by land of enhanced ecological value (a buffer);

II. further away patches of farmland enrol in ELMS in a way which creates a corridor of conservation land practice to connect to the nearest protected area, such as another SSSI (connectivity).

This spatial pattern of enrolment of farmland in conservation land practices could be achieved using the kind of Agglomeration Bonus (AB) described above, if it was incorporated as part of ELMS. Whilst actual applications of this idea are uncommon, much is now known about how best to design these kinds of spatial coordination incentives, based on experience gained from lab and field experiments (for a systematic review of this evidence, see Nguyen et al, 2021).

These kinds of incentives, for spatial coordination of conservation land use on farmland in the wider landscape, could be included within incentive payments to landowners on whose land the SSSI is located. As noted above, the policy design challenge for Natural England and Defra is to think about how to incentivise landowners to wish to improve the quality of SSSIs on their land, so that designation implies a benefit to the landowner rather than a cost. Landowners could be offered incentive payments to improve ecological quality of the SSSI on their land above some measured baseline, and made liable for reductions in quality below the baseline. This positive incentive payment could expand to include the neighbouring farmers (whose land connects to the SSSI) if they also adopted a conservation land management practice. Given that the SSSI enhancement payment is made to the landowner on who land the SSSI is located, this incentivises them to make offers (side payments, in the jargon of economics) to neighbouring landowners for them to adopt the conservation land management option. This SSSI-AB would be an alternative to the landscape-level AB described in the preceding paragraphs.

4.Conclusion

An economic perspective of the natural environment as natural capital regards it as a productive asset in the broadest sense. Biodiversity is characterised by the Dasgupta Review (2021) as an attribute of natural capital, which supports the ecological functions from which ecosystem services are provided. Greater biological diversity is equated to higher resilience of the asset and a range of benefits, but also as a critical and non-substitutable part of natural assets. This provides an economic justification for protecting biodiversity, including through the use of protected areas (PAs).

In applying environmental economics concepts on the value of biodiversity, a structure of direct, indirect, resilience and insurance values is used (see Annex 1). The economic value of PAs within this framework are often hard to measure: PAs don’t produce marketable goods and services, and we often do not measure most of the contribution of PAs to what economics traditionally sees as “values”. However, tools are available to fix this omission.

PAs have traditionally been designated based on scientific criteria. Arguably they have also been influenced, if only implicitly, by economic factors, such as the opportunity costs of conservation. While the basis for defining the boundaries of PAs may be scientific, a reason for having PA boundaries is partly economic - to restrict the areas affected by conservation measures, and thus the size of opportunity costs which society must incur. The introduction of economic values of nature as an additional criterion for protected areas network design would be a major change to previous scientific approaches.

The economic value of biodiversity aims to capture the different ways in which biodiversity contributes to human welfare. Incorporating economics into PA strategies needs to decide which types of values, for which beneficiaries, and over which timescales, should be considered. The natural capital approach (as per Bateman and Mace, 2020) would require consideration of all relevant values even if it may not be possible to identify, quantify and value all due to the limitations of scientific and economic analysis. The risk that analysis can skew towards more easily identified and valued benefits needs to be acknowledged. Prioritising different aspects of the contribution of biodiversity to human welfare will lead to very different PA strategies to maximise different types of values – for example seeking areas closer to population centres to maximise the recreational values of PAs. This may be preferred in some cases, but not in all (e.g. where what needs to be protected is located in remote areas, or where alternative target values are prioritised).

This economic thinking on PA designation and management also needs to factor in the dynamic effects of climate change. Biodiversity baselines and target condition are no longer static concepts, and a successful strategy requires connectivity, size and other features of PAs that enable adaptation to climate change. If economic analysis weighted potential future benefits more highly than it does at the moment, this would make investment in their provision more attractive now.

Climate change brings new factors to how economics could be applied to PA designation, including risks to lock-in certain strategies, the need to anticipate future conservation priorities under a changed climate, and the need to increase resilience and connectivity. These dynamic effects also have implications for how PA management is paid for, including the design of the forthcoming ELMS through spatial coordination incentives in landscape level schemes. There are no economic studies (that we are aware of) in the UK examining the value of non-PA habitats in PA connectivity. The relationship between PAs and surrounding land uses, in particular farming, should be subject to further research.

Economics is a useful tool to consider PA designation and management strategies. It can help society target specific benefits from PAs, and better consider their distributional effects. But its limitations need to be recognised.

Questions:

Relevant questions to help implement economic thinking within PA designation and management strategies, include:

- Which types of economic value of PAs (shown in Table 2) should society prioritise?
- How much do habitats providing buffer and/or connectivity to PAs add value to PAs?
- How can ELMS, and other incentives from private market payments for ecosystem services, help to more efficiently incentivise PA management? for example by:
    - shifting to a system that rewards good management (i.e. payments for results), and/or
    - incentivising connectivity and buffers for PAs and key habitats.

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Appendices

Annex 1: Value Framework:

The main distinction in the total economic value typology shown is between use value and non-use value. Use value arises from consumptive or non-consumptive interactions with a resource now or in the future – the latter referred to as option value. Non-use value is associated with individual's altruistic preferences for others living now (altruism), for future generations (bequest value) and for aspects of the natural world in their own right (existence value).

Source: eftec (2019) Feasibility Study for the Valuation of Forest Biodiversity, Final Report to Forestry Commission, September 2019. No copyright restrictions apply.

	Direct contribution to welfare	Indirect contribution to welfare		
Use value	*Direct benefits to households*	*Relationships between ecosystem services and production of final goods & services*		*Resilience value(s) – dependency on biodiversity for sustained ecological functions and process that underpin all contributions to welfare*
Consumptive use	Provisioning services: e.g. wild food	Provisioning services: e.g. timber and other forest products	*Insurance value(s): reduced variation in future income*	
Non-consumptive use	Cultural services: e.g. wildlife-based recreation, aesthetics and amenity, physical and mental health	Regulating services: e.g. carbon storage and sequestration, air quality regulation, flood regulation		
Option value	Future consumptive & non-consumptive use values	Future consumptive & non-consumptive use values		
Non-use value	*Direct benefits to households*			
Altruism, bequest and existence value motivations	Biodiversity conservation (e.g. threatened or priority species)			

Annex 2: Glossary and definitions of NRN characteristics

NRN terms

1. **Buffering**: Areas of reduced anthropogenic inputs (e.g. SSSIs) will remain central to our efforts to enable the natural environment to adapt to climate change. Buffering these sites, by creating a zone of low disturbance around each site, should be a priority. This will make the site ecologically bigger, less affected by edge effects, and thus more resilient and better able to support species dispersal.

2. **Refugia**: Prioritising protection and restoration in areas identified as being potential climatic refugia, such as landscapes with high levels of topographic heterogeneity, will help species and habitats to persist in areas despite changes in climatic and habitat suitability in surrounding areas.

3**. Connectivity**: improvements in connectivity is important at a range of spatial scales, but particularly south to north and altitudinal, to allow the redistribution of species with climate change.

4**. Focus on the most vulnerable**: Not all habitats are the same when it comes to the threat climate change poses, habitat creation, restoration and maintenance should focus on those most likely to be lost or degraded, such as montane, coastal, freshwater and wetland habitats.

5. **Natural Function**: encouraging naturally functioning ecosystems with enlarged SSSIs as ecological nodes within the NRN– SSSIs are unlikely to be able to support species and habitat adaptation without enlarging them to be able to support sustainable natural functioning of component ecosystems. A move to more natural ecosystem functioning will allow auto-adaptation by sites without constant management interventions. If SSSIs remain too small and highly managed, it is unlikely that we will achieve the target of 75% being in favourable condition by 2043.

Glossary

(Avoided) damage cost: Opportunity costs or resource costs associated with environmental impacts. Can include costs associated with natural events (e.g. flood damages to property) and longer-term deficits in environmental quality (e.g. drinking water treatment costs associated with poor water quality).

Altruistic value: Non-use value that individuals derive from the knowledge that other people benefit from (final) goods and services.

Bequest value: Non-use value that individuals derive from the knowledge that natural resources and the benefits gained from them are conserved for future generations.

Biodiversity: The variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part. Biodiversity includes diversity within species, between species, and between ecosystems.

Biomass: The mass of (living) biological organisms in an ecosystem. Net primary production is a measure of the change in biomass.

Consumptive use value: Benefits derived by individuals from the consumption or use of a good (e.g. timber, food products).

Cultural services: Non-material benefits that individuals derive from ecosystems, such as recreation, aesthetic enjoyment, health and wellbeing, knowledge gain, cultural identity and spiritual reflection.

Direct contribution to welfare (biodiversity) : Benefits from aspects of biodiversity that are final goods or services and contribute directly to individual and household wellbeing, such as wild food or wildlife-based recreation (e.g. bird watching).

Economic value: A measure of the benefit or wellbeing associated with the provision of a good or service. Ordinarily this is measured in monetary terms by an individual's willingness to pay (WTP) or willingness to accept (WTA) to secure or forego the good/service.

Ecological community: A group of plants, animals and other organisms that interact within a specific habitat.

Ecosystem services: The outputs of ecosystems processes that provide benefits to individuals and society as a whole, such as crop and timber production, carbon sequestration, flood risk attenuation.

Existence value: Non-use value that individuals derive from knowing that a resource continues to exist, regardless of use made of it, now or in the future.

Final good/service: The commodities, products, and services that individuals derive wellbeing from; i.e. the items that feature in a household's utility function.

Flow: The provision of a good, service, impact, benefit, cost, etc. measured over an interval of time (i.e. tonnes per year).

Indirect value/ contribution (of biodiversity): Contribution of some aspect of biodiversity – as an input - to the production of final goods and services, both market (e.g. timber) and non-market (e.g. air quality).

Insurance value: An aspect of economic value that relates to uncertainty over future flows of income and benefits due to unpredictable factors such as weather, disease, and fire. It is measured by the amount that a producer (i.e. forest manager) is willing to pay for the risk reduction that more diverse forests offer; for example accepting a lower average future return because it has lower variability (i.e. less risk of large falls in output), compared to higher returns but greater risk in terms of variability.

Market prices: The price at which buyers and sellers agree a transaction for good or service (see also 'exchange value').

Natural capital :The stock of renewable and non-renewable resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people.

Non-consumptive use value: Benefits derived by individuals from a good, service or resource that is not diminish by its use (e.g. nature watching).

Non-use value: Economic value derived from a good or service that is independent of, or not associated with its use, but is due to motivations based on altruistic, bequest and existence values.

Option value: The economic value associated with the potential future use of a resource (i.e. future use value).

Productive capacity: The ability of the (natural) asset to continue to provide ecosystem services and/or flows of resources.

Producer willingness to pay (WTP): Conceptually producer WTP should be equivalent to the marginal revenue product of an input to production. This represents the most a producer would be willing to pay for one more 'unit' of input and traces out their (derived) demand for the input.

Provisioning services: Material or energy-based outputs from ecosystem service provision, such as crops and food, timber, and pharmaceutical properties.

Regulating services: Beneficial outcomes that come from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a various biological processes, such as water purification, natural hazard regulation (e.g. flood protection), assimilation of waste, local air quality regulation.

Replacement cost method: A proxy approach for measuring for the value of a good or service that is based on the cost of replacing it using a substitute technology if it is lost or if its productivity decreases; for example, valuing wild insect pollination based on the cost of hand pollination.

Resilience: The degree to which a specific ecosystem function can resist or recover from an environmental or external shock and maintain a level of functioning above a specified level or threshold.

Resilience value: The economic value that can be attributed to maintaining specific ecosystem service outputs over time despite risk factors like variability in environmental conditions, disturbance due to external pressures, and management uncertainty.

Species diversity: The variety of species within a habitat or community. It accounts for both species richness and species evenness (which measures the relative proportion of different species in a community).

Species richness: A measure that is a count of the number of different species within a community (with no account for the relative abundance)

Stock: The quantity or value of a capital asset at a specific point in time.

Supporting / intermediate services: Ecosystem services that underlie and are necessary for the provision of all other ecosystem services (provisioning, regulating, cultural), such as soil formation and retention, nutrient cycling, and water cycling.

Total economic value: The sum of use and non-use values derived from a good, service or resource. Travel cost method See recreation demand models

Treatment cost: Resource costs to health services from treating physical or mental health conditions. Strictly this is not a component of household utility, but it may be used as a cost-based proxy or would represent a lower bound estimate of the value of an impact (i.e. excluding welfare impact).

Use value: The economic value that is derived from using or having potential to use a resource. It is the net sum of direct use values, indirect use values and option values.

Welfare: A measure of satisfaction or 'utility' gained from consumption or use of a good or service.

Willingness to accept: Monetary measure of the economic value or benefit that an individual derives from the provision of a good or service, measured in terms of the minimum amount of money (income) they are prepared to receive in compensation to forego its provision.

Willingness to pay: Monetary measure of the economic value or benefit that an individual derives from the provision of a good or service, measured in terms of the maximum amount of money (income) they are prepared to give up to secure its provision.

Annex 3: Current payment system

If a scientific case for SSSI designation may no longer to considered to be persuasive enough. The economic values generated by maintaining (and improving) the system of SSSIs, and/or protected areas in general, can be viewed as an additional reason why maintaining the network is a good idea.

Ideally, we need SSSI designation not to be perceived as a cost or burden by landowners. One issue with the US Endangered Species Act has been the wrong incentives to landowners, who see designation of sites as imposing restrictions and thus costs on them – led to incentive to damage sites so they were either not designated in the first place, or became so degraded they were de-designated (Brown and Shogren, 1998; Langpap et al, 2018).

The WRONG way to fix this problem is the arrangements under the Wildlife and Countryside act (1981) commented on by Spash and Simpson (1994) – offer compensation payments when landowners threaten potentially damaging operations. This allows landowners to exploit information asymmetries and extract information rents from the Agency, since the Agency does not know which threats are for real. Spash and Simpson point out that this led the NCC to have to prioritise which SSSIs to protect since it had a fixed budget for compensation payments. The implied property right designation is the problem here – landowners have the right to damage an SSSI if they want to.

A better way to fix the problem is offering payments for positive actions, rather than to avoid negative actions. This is the principal that underpinned Environmentally Sensitive Area payments, and then Countryside Stewardship. With regard to SSSIs, a 2-part payment could be envisaged:

Maintenance level payment: To partly offset the perceived cost to landowners of SSSI designation on their land, a PES-type payment could be offered which would be paid so long as the quality of the SSSI does not fall below a baseline level - which could be the level which applies at the time of agreeing the contract. Landowners would not be allowed to degrade the SSSI deliberately below the baseline through their land management decisions, but would receive funding for actions they take which maintain the SSSI at this baseline level. The payment signifies that the state recognises the public goods being delivered from the landowners' property at this baseline level. This payment could vary regionally according to differences in agricultural productivity (e.g. measured as mean Gross Margin per ha.).

Improvement payment: If landowners can improve the quality of the SSSI above the baseline by an action such as reducing stocking rates or fertiliser application rates, then an additional payment is offered to landowners, based on the estimated costs of the improving action. This payment rate would be set higher than the maintenance-level payment, and could again vary regionally according to differences in agricultural productivity, since these reflect the opportunity costs to the farmer of actions which improve SSSI quality.

Since the opportunity costs of conservation action varies across landowners, offering a fixed-rate subsidy to all land managers who enrol in a conservation scheme will not be cost-effective. This means that PES type payments should vary across landowners who each perform the same set of actions or achieve the same environmental outcome. A varying-rate payment scheme has been shown to be around 70% more cost-effective for bird conservation on farmland in the Peak District, for example, compared to the kinds of uniform payment rate that are offered under Countryside Stewardship (Armsworth et al, 2012). However, the regulatory agency will often have poor information on what the costs to each individual farmer are of changing their management to a more pro-conservation regime. This makes calculating these variable payment rates more difficult. Conservation auctions (e.g. Rolfe et al, 2017) are one solution to this problem of “hidden costs”.

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