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ERAMMP Report-102: Natural capital in payment rates

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Abbreviations Used in this Report

BAP	Biodiversity Action Plan
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CE	Choice experiment
CO_2-e	Carbon dioxide equivalent
CoGAP	Code of Good Agricultural Practice
CP	Dry year critical period
CV	Contingent valuation
DYAA	Dry year annual average
ENCA	Enabling a Natural Capital Approach
ERAMMP	Environment and Rural Affairs Monitoring & Modelling Programme
GHG	Greenhouse gas
IMP	Integrated Modelling Platform
JULES	Joint UK Land Environment Simulator
MENE	Monitor of Engagement in Natural Environment
NAEI	National Atmospheric Emissions Inventory
NPV	Net present value
NVZ	Nitrate Vulnerable Zone
NWEBS	National Water Environment Benefits Survey
ONS	Office for National Statistics
ORVal	Outdoor Recreation Valuation Tool
PV	Present value
QALY	Quality Adjusted Life Years
UA	Universal Actions
RBDs	River Basin Districts
SFS	Sustainable Farming Scheme
SLM	Sustainable Land Management
SSSI	Sites of Special Scientific Interest
UKCEH	UK Centre for Ecology & Hydrology
VfM	Value for Money
WFD	Water Framework Directive
WORS	The Welsh Outdoor Recreation Survey
WRZ	Water Resource Zone
WTO	World Trade Organization
WTP	Willingness-to-pay

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1 EXECUTIVE SUMMARY

This report has been prepared by eftec and ADAS, as part of the UK Centre for Ecology & Hydrology (UKCEH)-led ERAMMP programme, to assess the inclusion of social values from natural capital in SFS payments. It aims to provide an evidence base and policy advice for the Welsh Government to support inclusion of social values from natural capital into agricultural policy. It looks at the spatial and temporal variation of estimated social value of public goods provided by natural capital (i.e., benefits from the natural environment not captured by markets) across Wales.

The evidence base demonstrates that the natural environment provides significant social value to people in Wales. However, there is significant variation in social values from natural capital across Welsh regions. Where the evidence can be disaggregated to scales suitable for delivering public policy objectives (e.g., catchments, local authorities), benefits from different locations can vary by more than an order of magnitude (up to a multiple of 50). This means, for a given farm type and associated cost profile, SFS actions will achieve significantly different value for money in different parts of Wales.

A socially efficient set of SFS payment rates (i.e., per hectare payments to land managers to deliver SFS outcomes) would therefore be tailored to reflect variation and differences in the size (£) and delivery of environmental outcomes (enhancement to or from nature) from the same SFS actions in different locations across Wales. The reasons for variation in social outcomes across Wales are different for different benefits. They relate to a) changes in environmental outcomes arising from SFS actions (e.g., sequestration and evapotranspiration rates differ by type and maturity of woodland species mix), and/or b) socio-economic characteristics determining how people interact and benefit from nature (e.g., size of location of population).

How social value varies provides a set of options for inclusion in payment rates. Per hectare payment rates should take into account each of the following considerations. Firstly, payment rates could be **targeted based on social value** of environmental outcomes. The present values of environmental outcomes delivered by SFS actions which enhance, protect or restore natural capital across Wales may be valued at up to several £100,000s per ha over a 75-year period (in the case of carbon sequestration and emissions avoided from woodland creation, peatland restoration and actions to management nutrient run-off). Social value arising from SFS action exists beyond carbon however, with air quality, recreation and physical health benefits likely to arise which can be worth up to £50,000 per hectare over the same scale of time. Evidence from this report and future IMP model runs would inform these exact rates, and location-specific variations in rates and environmental outcomes. This is preferable for those benefits where valuation evidence exists and is sufficiently robust to model (e.g., carbon, air quality, recreation, physical health).

Secondly, rates could vary with **delivery of SFS** actions which deliver environmental outcomes (i.e., physical actions that are a proxy for providing increased social value from natural capital). This is feasible for several benefits (e.g., natural flood risk management, water supply, biodiversity, and managing nutrient run-off) where suitable proxies for social values are difficult to determine and not suitable for incorporation into SFS payment rates. However, for these benefits there is sufficiently robust evidence which demonstrates that habitat management and creation will deliver important strategic SFS objectives. SFS payment design should not ignore these benefits, but rather link payments in locations for actions which, based on the best available evidence, are most likely to deliver these outcomes (e.g., woodland creation in targeted flood risk areas).

Thirdly, rates could vary in **locations where SFS actions delivery benefits larger human populations** (e.g., payment rates increase as the number of people who benefit increase), since the values from air quality, recreation and physical health typically scale with beneficiary human population size.

Finally, rate variation should **consider where income forgone for land managers is highest.** Like social value, the income forgone to deliver SFS actions is not uniformly distributed across Wales. This variation exists not only between land use types (e.g., comparing arable and dairy farm activities), but also within a given land use (e.g., different dairy farms have different income forgone). Since land use varies across Wales, this means that costs to delivering SFS actions also vary spatially in particular when reduction in livestock density is needed. Where income forgone is higher, flexibility in per hectare payment rates will be efficient to incentivise land managers which face higher costs but also deliver higher levels of social value from those actions.

Practically speaking, this means per hectare payment rates should be higher in those locations across Wales where actions deliver higher social value, and where the associated income forgone is larger. This approach balances public policy objectives to maximise efficiency of public monies (promoting the greatest value for money from the scheme) and effectiveness of scheme design (promoting the highest environmental outcomes). Flexibility to target higher per hectare payment rates where social value is greatest is critical for the optional and collaborate layers of the scheme. This can help maximise the social value from Welsh farmland under the SFS by incentivising voluntary uptake of single-farm or cross farm actions which have higher opportunity costs but deliver greater social value through achievement of SFS objectives. Further IMP modelling should explore how the inclusion of social values in payments rates under the collaborative and optional layers will influence farm uptake and delivery of environmental outcomes at scale.

Policy design incorporating spatial variation is complex and not without risk. There are risks relating to non-delivery of environmental outcomes from public monies. This could be due to land managers not undertaking the agreed actions, or due to SFS actions not producing the intended environmental outcomes. In particular, where value varies based on natural processes, the annualised value of the benefits (£/hectare/year) is likely to change (usually increase) over time since benefit flows often are a function of habitat maturation. Generally, payment rates based on short-term benefit delivery will attribute a greater weight towards a specific mix of benefits that materialise more quickly (e.g., water quality, recreation, physical health, reductions in emissions from reduced livestock density) than others (carbon sequestration and air quality). Temporal considerations are therefore a necessary design feature of efficient payment rates since SFS objectives should be measured over longer timescales to take into account the wellbeing of future generations.

Regarding design risk, generally there is good evidence and mapping of habitat, accessibility and vegetation which would facilitate the inclusion of carbon reduction (including atmospheric carbon and reduced emissions from livestock), recreation and air quality values into payments. Where published valuation evidence is less robust for inclusion in payment rates and data availability (at various scales e.g., for biodiversity, flood risk management and water supply) is limited, it is more difficult to include these values with high confidence.

To address these risks in payment design, it is advisable to use a) annualised present values per hectare, and b) 75-year period of assessment in payment rates. This balances risks of high up-front costs to both farmers and public spending, relating to a) low up-take from land mangers (since some proportion of long-term social value is redistributed to land managers in the early years of SFS action), b) non-delivery SFS actions from farm manager actions, and c) SFS actions being undertaken but unsuccessful in achieving environmental outcomes.

2 Introduction

eftec and ADAS were commissioned by UK Centre for Ecology & Hydrology (UKCEH) to provide an evidence-based assessment for the Welsh Government of the extent to which “social values” from the natural environment in Wales can appropriately be incorporated into different agricultural and land use payment approaches, namely:

1. Flat-rate per hectare payments which are not targeted and available to all eligible farms;
2. Per hectare/metre/etc action payment which could be available on a prioritisation basis (e.g., where most outcome could be delivered); and
3. Grant funding for bespoke collaborative projects at scale.

The term ‘social value’ is defined and scoped as referring to the value to Welsh society from the public goods provided by the natural environment in Wales. This definition means that market goods and transboundary impacts are excluded, so the emphasis is on non-market impacts.

This interim evidence report on flat rate and action payments presents eftec and ADAS’ findings from a review of evidence in selected sources relating to eight specific non-market benefits provided from natural capital: atmospheric carbon reduction, water quality, air quality, recreation, physical health, flood risk management, biodiversity and water supply. These benefits were selected since they are routinely assessed using existing sources of evidence in the UK, and those that allow for mapping against the actions and outcomes of the Sustainable Farming Scheme (SFS)[1].

2.1 Project background

The setting of payment rates for agri-environmental support involves various approaches. The dominant method involves estimating the costs incurred and income forgone by farmers as they implement specific management actions to deliver desired outcomes. This method aligns with World Trade Organization (WTO) and EU Green Box requirements and offers simplicity and transparency by using observed farm-level data. It is important to note that classifying payments as ‘Amber box’ removes the need for compensation justification, allowing for alternative payment calculations.

The costs incurred and income forgone approach calculates payment rates based on the additional costs and income losses per unit of a specific management action on a typical participating farm. However, the approach has its weaknesses. It fails to account for the heterogeneity of farms and may over-compensate some while under-compensating others. Additionally, it lacks financial incentives for farmers to enrol in agri-environment schemes, as transaction costs can significantly raise total farm costs. Moreover, income forgone estimates can be affected by market volatility, and the approach may not encourage alternative earning potential for farm labour in non-farm uses. Payment rates also require frequent adjustments due to changing unit costs and output prices.

[1] See here for an outline of the Sustainable Farming Scheme: www.gov.wales/sustainable-farming-scheme-guide

Alternatively, a top-down 'social value' approach could be used, where payments are based on the value of the delivered public goods to society rather than specific management actions. This method allows flexibility in achieving outcomes and may offer higher payment rates, which in turn may better incentivise land managers. Nevertheless, operationalising this approach is challenging due to the absence of market prices to guide value assessments. Ecosystem complexity and the joint production of agri-environmental outcomes with agricultural outcomes further complicate the operationalisation of this approach. Additionally, different groups of beneficiaries at various scales make aggregating benefits and valuing individual outcomes challenging.

The purpose of this report is to help understand how to reflect the social value of the environment in payments that could be made to farmers and other land managers under Wales' forthcoming agricultural policies (the SFS). This project adopts the natural capital approach[2], so a core focus is on analysing the monetary value of benefits derived from the natural environment. Through this approach, the natural environment is regarded as an asset that provides benefits to people over time. The state of the natural capital assets can be influenced by external factors (including natural processes, and human-induced climate change), and how the assets are maintained and/or exploited by people. Agricultural policies and payments are a key influence on land managers' behaviour and hence natural capital in Wales.

2.2 Project objectives

Through gathering evidence on the social value of natural capital in Wales, this project aims to help incorporate social values into a payment methodology for the SFS.

The three main outputs of this project are as follow:

1. Evidence Review (the interim report)
2. Interim Evidence Report on flat rate and action payments – early August 2023
3. Final Interim Evidence Report on flat rate, action and collaborative payments – October 2023
4. Final Evidence Report on flat rate, action and collaborative payments (this report) – November 2023

This final evidence report summarises the available evidence and provides results in terms of the magnitude of specific natural capital benefits and how payments can be spatially targeted. It includes examples of relevant data, in line with the data characteristics reviewed (see Section 3), and focuses on answering:

- Value for Money (VfM) – how will the incorporation of social value into the payment methodology influence value for money?
- Data availability/accuracy – are the data available (including through value transfer) at the appropriate granularity for measuring outcomes and incorporating into the payment methodology?

[2] A natural capital approach "integrates the concept of natural capital into decision-making" through capital terms thinking, which "enables comparison of many changes and decisions at the same time." See here for more details: https://naturalcapitalcoalition.org/wp-content/uploads/2019/06/NCC-WhatIs-NaturalCapitalApproach-FINAL.pdf

This final report relates to flat rate and action payments on evidence that could be used to incorporate natural capital values into the Layers 1 and 2 payment rates for the upcoming SFS and reports the evidence that can be used to incorporate natural capital values into the payment rates used for all three layers of the SFS, including payments for collaborative actions by farmers. The report provides breakdowns of the relevant data, and/or descriptions of how to use the evidence sources available to derive such data.

Ultimately, the findings from this project will help the Welsh Government consider different payment methods in light of natural capital benefits and social values and assess issues pertinent to environmental outcomes and delivery of a payment scheme at scale.

In undertaking this work, the analysis of natural capital values bears in mind the need to address the questions and issues in Section 3.3.

2.3 Report structure

The remainder of this report is structured as follows:

- **Section 3** introduces the evidence review method, including the scope, research approach and benefits covered in this assessment;
- **Section 4** outlines findings on spatial variation of the value of natural capital, application of benefit values under Universal Action layers, and potential delivery risks in natural capital payment values; and
- **Section 5** presents conclusions in the context of initial findings in this interim evidence report on flat rate and action payments and discusses next steps.

Annex 1 summarises key findings from the evidence review findings along the eight benefits: atmospheric carbon reduction, water quality, air quality, recreation, physical health, flood risk management, biodiversity and water supply.

Annex 2 provides data tables gathered from the evidence review relating to each of the benefits covered in this report.

Annex 3 expands on the benefit values in Section 4 and Annex 1 by providing additional present values for water quality, air quality, recreation and physical health benefits. This section describes the variation in natural capital values between local authorities and catchments, and over time.

Annex 4 outlines the details of SFS bundle 3 on nutrient and land management from the IMP model runs.

Finally, **Annex 5** provides data tables of estimated income forgone for the creation of semi-natural and woodland habitats. Tables were sourced from the Welsh Government project C280/2019/2020 Phase 2 and 3 reports undertaken by ADAS, Pareto Consulting and SRUC on farm-level costs of proposed SFS Universal Actions measures.

3 REVIEW METHOD

This section describes the method used to review the physical and economic evidence to address the questions outlined in Section 1, to provide the findings in Section 4.

3.1 Introduction

The evidence review is based on sources already used to inform analysis of natural capital values in the ERAMMP work programme (e.g., ENCA (Defra, 2021)) and the priorities under the SFS policy. The following steps were taken for collecting and collating available literature to establish an evidence base:

- Develop a research approach;
- Search for evidence and produce a database; and
- Extract relevant evidence.

The search scope and the identification of sources are described in Sections 3.2 and 3.3. The evidence found is reported in Section 4, accompanied by specific findings from the benefits[3] review and data tables for each benefit in Annex 1 and Annex 2, respectively. The resulting evidence is then synthesised to identify common themes and trends which describe the key drivers of spatial variation in the social value of benefits. This also includes data gaps and barriers to the inclusion of certain benefits within natural capital payments in the SFS.

3.2 Scope

The scope of the evidence review was to identify sources that measure spatial variation of social values from natural capital. The evidence review started by identifying a list of benefits within the scope of this project. The benefits within scope are those that are routinely assessed using existing data and evidence sources within the UK.

The evidence review focuses on key literature that discusses how the value of the benefits from the management of natural capital by farmers varies across Wales. It has collected and synthesised, from specific evidence sources, physical and economic modelling, and valuation evidence. The key sources of evidence were:

- Wales-Relevant Policy Evidence – Policy evidence that can be practically applied in Wales – based on Defra's ENCA guidance, which serves as a key source of evidence on natural capital, recognised in HM Treasury's 'The Green Book' guidance on policy appraisal by Government. This includes referenced literature within ENCA.
- IMP model runs. This was limited to one intervention bundle – SFS3 10 and 30 (see Annex 4).
- ADAS research e.g.:
    - Potential economic effects of the Sustainable Farming Scheme (SFS). Phase 2 (Moxey et al., 2022) and Phase 3 (Thomson and Moxey, 2023) reports;

[3] It is possible that disbenefits can arise from natural capital. In the context of agriculture, the common example is methane emissions from livestock. However, since this report focuses on social values arising from managing Welsh farmland to promote the delivery of environmental outcomes, we refer throughout the report the positive benefits arising from natural capital.

- Farmscoper V5 – calculating farm and catchment scale pollutant losses (particularly the Farmscoper Evaluate tool); and
- Regulatory Impact Assessment (RIA) for potential regulatory approaches to reduce agricultural ammonia (NH_3) emissions in Wales.

Specific data-related questions which we sought to answer through the evidence review, for each benefit within scope, are outlined in Section 3.3.

3.3 Research approach

The benefits reviewed were identified based on a quick overlap analysis between the following data sources:

- Defra's ENCA (2021) guidance. This source collates UK-based evidence on physical and economic metrics of readily valued benefits from nature.
- The Outline Proposals for 2025: Sustainable Farming Scheme, first published in 2022. In particular, page 10 documents outcomes which will be targeted by the SFS.

Benefits were selected based on the below criteria.

- The benefit type appears in both the ENCA guidance and the Outline Proposals, and
- There is at least medium confidence, as assessed by Defra, in both the physical and economic evidence, **or**:
- The benefit is low confidence but is deemed to be either of strategic importance for the SFS (i.e., maps clearly to an outcome in The Outline Proposals for 2025), or the evidence is of sufficient quality to describe variation and uncertainty.

Table 1 shows the list of benefits that are within scope of this report, along with the type of ecosystem service it is categorised in ENCA (Defra, 2021) and a description of the benefit.

Table 1: List of benefits covered in this report

Benefit name[4]	Type of ecosystem service	ENCA Description (Defra, 2021)
Atmospheric carbon reduction	Regulating	Sequestration and storage of carbon dioxide by growing vegetation, soils and sediments
Water quality	Aggregate/bundled	Provision of clean water by nature
Air quality	Regulating	Removal of harmful air pollutants from the atmosphere through a) direct deposition onto leaves and bark and b) internal absorption of pollutants through stomatal uptake
Recreation	Cultural	Environmental settings for recreational use
Physical health	Cultural	Environmental settings for physical activity
Natural Flood risk management	Regulating	Regulating water flow by vegetation retaining water and releasing it slowly, or absorbing wave energy
Biodiversity	Aggregate/bundled	Defined by the Convention on Biological Diversity (CBD) as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological

[4] Three benefits reviewed have different names in ENCA (2021): atmospheric carbon reduction is "carbon reduction", air quality is "air pollutant removal" and flood risk management is "flood regulation".

		complexes of which they are part, this includes diversity within species, between species and ecosystems". As such, biodiversity underpins all ecosystems and the services that they provide.
Water supply	Provisioning	Surface and groundwater for various uses.

From the short-list of benefits, we reviewed the evidence sources listed above and documented key summary information of the source and key parameters of interest. Of particular interest and focus is evidence, at both a physical and economic level, which describes whether the physical flow or economic value of natural capital benefits varies across spatially or temporally. The type of information is outlined below:

Physical evidence

- Physical flow metric of the benefit within scope
- Range of physical flow of benefits (physical unit/year). Where possible, physical unit per hectare or kilometre per year i.e., including spatial and temporal elements.
- Data sources and methods of collection
- Key determinants of spatial variation in physical flows of benefits within scope:
  - What is the variable influencing variation over space?
  - Why/how does it lead to variation?
- What are the key uncertainties associated with spatial variation?
- What is the confidence associated with the physical evidence?

Economic evidence

- Valuation unit e.g., £/physical unit/year
- Type of valuation method
- Range of monetary values (i.e., £ per hectare or kilometre per year) of each benefit within scope
- Data sources and methods of collection
- Key determinants of spatial variation in economic valuation of benefits within scope:
  - What is the variable?
  - Why/how does it lead to variation?
- What are the key uncertainties associated with spatial variation?
- What is the confidence associated with the economic evidence?

Where available, data tables describing the ranges of physical units or values over space, or which are relevant for describing variation, are recorded in the Annexes of this report.

Throughout this report, benefits are assessed relative to a baseline scenario where 'baseline' refers to the counterfactual or existing land management pre-SFS. Benefits may be calculated as either a) additional social values arising from specific SFS actions, or b) the social value provided by a given habitat. The former is important since it outlines the potential social value delivered by the SFS; the latter to promote the social importance of the natural environment more generally.

The focus of this report is additional social value from SFS actions and how this varies across space in Wales. Assessment of the significance of variation of social values is based on expert judgement combining evidence on the absolute size and relative size of the variation in value.

There is no precise rule because for different absolute size of benefit values, different proportionate variations in value can be material to potential payment rate design.

Benefits are calculated using the following assumptions:

- 75-year period of assessment to mirror the IMP time horizon. We have also used 5-year, 10-year, 25-year and 50-year figures for comparison in the relevant sections.
- Use of discount rates is in alignment with The Green Book (HM Treasury, 2022) and IMP modelling. For carbon reduction, water quality and recreation, a 3.5% discount rate, reducing to 3% from year 31. For health-related benefits from air pollutant removal from vegetation, a 1.5% discount rate is used, reducing to 1.29% from year 31.
- Prices have been inflated, where original evidence is in an earlier year, to 2022 price levels using GDP inflators and indices. The IMP price levels are the same as the base model.
- In the case of water quality benefits, values have been assessed for each Welsh catchment and river basin district using the National Water Environment Benefits Survey ("NWEBS"). Values are reported based on an indicative change in ecological status, deemed to be from poor to moderate. This assessment does not consider the likelihood of SFS actions delivering this change in status. Values reported by the IMP model are also reported in Annex 1, which are more specific and reports value based on the current status of the water body or river and whether SFS actions change the status of the waterbody.
- With respect to the IMP analysis, we have presented the results from SFS bundle 3 (nutrient and improved land management) 10 (using 100% Glastir payment rates) and 30 (using 130% Glastir payment rates), since these demonstrate potential variation in size of value distribution across Wales. Details of SFS bundle 3 are in Annex 4.

4 Findings

This section on findings is structured as follows:

- Values of natural capital benefits from delivering SFS outcomes (Section 4.1)
- Spatial variation of the value of natural capital benefits (Section 4.2)
- Application of natural capital benefit value to the Universal Actions layer (Section 4.3)
- Evaluation of risk of varying payment rates by value evidence (Section 4.4)

4.1 Values of natural capital benefits from delivering SFS outcomes

This section discusses the range of valuation evidence of the natural capital benefits reviewed, with more details outlined in Annex 1. Different variables drive the variation in values per hectare of different benefits. These are discussed in Sections 4.2 and 4.3. A notable conclusion from the benefit review is that the present values[5] of the benefits analysed have significant ranges. These are described below.

- **Carbon reductions from sequestration or reduction in emissions** relate to woodland and peatland habitat management. The present values from these habitats over 75 years are valued at several £100,000s per ha. Per annum, this equates to present value per hectare of up to £4,000 (for woodlands) and £5,000 (peatlands) over 75 years. Social values of carbon reductions from woodland planting are driven by environmental characteristics (e.g., site conditions, climate) and appropriateness of habitat creation given existing land use (e.g., excess soil compaction from previous grazing activities), which are likely to vary across Welsh regions.

- **Air pollutant removal by creation of new woodland** has health benefits worth between £10 and £800 per hectare (annualised value over 75 years) across local authorities in Wales. This variation is driven by proximity of woodland to greater numbers of people density. The present values for this benefit over 75 years are valued at £100s to over £50,000 per hectare.

- **Benefits from recreation from creation of new accessible green space** also show a large variation across local authorities in Wales – between £400 per hectare per year in Cardiff versus £22 per hectare per year in Powys (annualised value over 75 years). This variation (approximately a factor of 20) is driven by proximity of accessible green space to greater numbers of people. The present values for this benefit over 75 years are valued at £1,000s to as much as £30,000 per ha.

- **Benefits from physical health from creation of new accessible green space** also show a large variation which matches the pattern of recreation – between £400 per hectare per year in Cardiff and £6 per hectare per year in Powys. This variation (approximately a factor of 60) is also driven by proximity of accessible green space to greater numbers of people as this strongly influences the numbers of recreational visits.

[5] Present values are calculated over a 75-year period (PV75) using HM Treasury recommended discount rates.

The present values for this benefit over 75 years are valued at up to £27,000 per hectare in Cardiff.

- **Values for water quality benefits** are harder to calculate, but the annualised present values per kilometre of river over 75 years vary between £1,000 and £2,000. The size of this variation between Welsh catchments is much lower than variation between local authorities for air quality, recreation and physical health benefits.

Evidence from the previous Integrated Modelling Platform (IMP) model runs (which models various SFS actions and outcomes) describe the social value of various SFS management bundles. The modelling describes how social value changes as more farmers opt into the scheme, in comparison with a baseline land management outside of the SFS. This evidence also demonstrates that the present values of benefits arising from carbon reduction are an order of magnitude larger than air quality, water quality and recreation (see Section 3.3 and Annex 4 for more details).

For flood risk management, biodiversity and water supply benefits, the evidence base suggests that there is likely to be significant spatial variation in social outcomes from SFS actions, however the valuation evidence is less robust. These are described in more detail below:

- Natural Flood risk management benefits arising from SFS actions should be expected to vary spatially according to catchment hydrology, specific management actions undertaken, habitat (or land use) type, climatic conditions (including because of climate change) and downstream location of properties at risk of flooding. There is national and regional flood risk management modelling across Wales to support policy targets which aim to reduce the impact of flooding on local communities, businesses and key services (e.g., education). However, this modelling does not assess the contribution of habitat creation (e.g., woodland) or watercourse management to alleviating flood risk.

  Current valuation evidence is based on replacement cost approaches, which are not deemed as suitable proxies for inclusion in payment rates. An avoided damages approach, which calculates the reduction in average expected damages to residential and commercial properties arising from woodland or watercourse management, is methodologically feasible but requires site-specific and catchment-relevant modelling, and transferability of values in the literature is a challenge. In addition, most evidence of the benefits from woodland or watercourse management is model based, generated at small spatial scales (catchments < 1km^2), and currently there is inconclusive evidence that benefits would arise for medium or high impact flooding events. Incorporating sufficiently robust values into payments to support catchment-wide action therefore requires better understanding of the contribution of scaling up farm and catchment scale woodland creation and habitat management across Wales, which to date is currently unavailable.

- Biodiversity benefits vary widely depending on the specific benefits being valued (often a bundle of different attributes) and are challenging to quantify and value in a robust and consistent manner across Wales. There is likely to be spatial variation across Wales on a habitat-by-habitat basis, but unit transfer of existing evidence would not be recommended. However, it should be noted that new evidence on benefits of biodiversity is awaiting publication (eftec forthcoming) so this conclusion should be kept under review.

- Water supply benefits are also likely to show spatial variation, depending on local industrial and residential water use, as well as availability in the water table. As with flood risk management, detailed modelling and assessment of future water demand and supply trends across Resource Management Zones is undertaken every five years by water companies. These plans highlight high risk areas identified as those where projected demand exceeds supply, and describe actions to increase supply, reduce demand, and/or manage leakage and efficiency.

Whilst this modelling exists, there is little published site-specific evidence supporting the contribution of habitat management or creation to improving water supply across Wales. Regarding valuation, it may be possible to calculate average £/m^3 unit values from UK natural capital accounts, or b) access cost data as a proxy from water companies' annual reports. However, both methods have difficulties since it should be expected that there will be variation in the costs associated with water abstraction depending on forecast trends in demand and supply for water, alongside the capability and capacity of existing infrastructure.

4.2 Spatial and temporal variation of the value of natural capital benefits

Social values of natural capital benefits across Wales can vary by several orders of magnitude for certain benefit types. The reason for this variation differs between benefit types.

To summarise, nearly all benefit values (£/hectare/year) vary spatially across Wales. The reasons for this variation differ by benefit as outlined below and in Table 2. The level of variation is significant enough to mean that greater social value could be achieved through varying payments for SFS actions to target locations which deliver higher levels of benefits.

There is also strong evidence around the size of these benefit variations across Wales. This is particularly clear for population dense areas, where the unit value of benefits is an order of magnitude greater than sparsely populated areas of Wales. Additionally, some unit benefit values (per hectare per year) increase over time, and some increase (or decrease) as actions to deliver them increase in spatial extent (i.e., contiguous hectares under SFS management are increased). **For these benefits, varying rates under the optional and collaborative layers should be preferred to incentivise land managers to deliver benefits where they are likely to be highest (see Section 5)**.

There will be regions in Wales where a fixed payment rate will achieve significantly different VfM from actions by different farmers. The extent of this variation in VfM will also depend on the costs to deliver the actions. Details of the variations and how they can be integrated into a payment are outlined in Table 2. Key points are noted below. Note that the valuation evidence does not consider the impact of climate change on the variation of provision of benefits and their values across space (e.g., implications for availability of water supply, severity of weather events and flood risk downstream).

1) **The monetary values of carbon benefits vary depending on the ecological functions of a specific habitat and land management actions.**

   Carbon sequestration quantity flows (hectare/year) are driven by habitat type (although there is some variation depending on the actions undertaken). £ values per hectare per tonne of carbon dioxide equivalent (£/tCO_2-e) do not vary based on geographical location or political jurisdiction; the £ value to society per tonne of carbon sequestration is the same in the North East of Wales as in the South West. Total £ values vary across Wales depending on either a) the proportions of different habitats in different areas, b) locations where habitat creation is suitable (e.g., woodland creation is not permitted under the

Universal Actions (UA) layer on existing peat soils), and c) which land management actions are undertaken (e.g., planting of specific species).

Based on the IMP modelling outputs, there are significantly higher potential carbon benefits in the South West in comparison with the North West due to higher livestock density. Therefore, fixed payment rates will likely pay less than the value of carbon benefits for farmers in the South West in comparison with the North West. The size of this under/over-payment depends on the choice of carbon benefit value (i.e., whether the payment is based on a lower bound estimate).

2) **Other natural capital benefit values vary across space depending on the ecological functions of a specific habitat, land management actions and their location relative to the beneficiaries**.

The relative importance of environment and socio-economic factors varies across benefits. For instance:

- Water quality benefits depend on both addressing water pollution pressures and having impacts in catchments with greater numbers of people.

- Air quality benefits of woodland are more dependent on the socio-economic location. The value (£/hectare/year) is greater in or adjacent to urban areas, where vegetation is situated close to greater numbers of people. This is a function of both physical and economic data:

    - There is more pollution in areas with higher population, so the vegetation removes more pollutants from the atmosphere.

    - There also are more beneficiaries (people protected from exposure to pollutants) and, therefore, from the combination of these factors the total £ benefits (in avoided medical costs) are significantly larger.

- The same is true for recreation (higher benefits are found closer to greater numbers of people) and physical health (which is based on 'active' recreation visits) where high total £ values correlate closely with areas of high population, density: £ values per hectare are larger in the South Central region of Wales, and are lower in the North West and Mid Wales. Therefore, fixed payment rates using the lower bound of the range of values for these benefits will pay less than their social value in South Central Wales, in comparison to North West and Mid Wales.

3) **Some values of natural capital benefits are mainly driven by socio-economic factors.** For instance, the physical health benefit from natural capital is the contribution of nature to avoided medical costs arising from physical activity. The benefit does not vary significantly between habitats (although certain habitat types can incentivise more activity). Ease of access to recreation site (e.g., time and costs incurred to travel to a given site) and numbers of beneficiaries are each important variables to consider.[6]

[6] Note that the recreation and physical health benefits do not consider variations in habitat quality and condition. All habitats are assumed to have the same condition regardless of location in Wales. See Annex 1.

The physical health benefit therefore spatially maps to recreation activities: where there are more recreational visits of a certain profile (e.g., length of time), there are likely to be better health outcomes, but the health benefits themselves are not necessarily a function of the habitat type.

4) **Per hectare values may also change (e.g., increase or decrease) with the spatial scale of delivery and over time.** When creating new woodland, the annual quantities of carbon sequestered and the amount of pollutant removed from standing vegetation change as the woodland matures. The valuation models used assume that it takes 40 years for the maximum annual air pollutant removal and carbon sequestration rates to be achieved. Until year 40, the amount of benefit per year increases linearly. This means that annualised present value (£/hectare/year) for air quality and carbon sequestration benefits will increase over time. This variation may be as much as seven times greater over longer timescales (75 years) than shorter timescales (5 years).

   Similarly, biodiversity benefits of a given habitat are likely to increase over time. Management actions will not immediately restore habitats or instigate return of target species, nor will habitat resilience or connectivity be restored, or realise its full benefits, immediately. Although these benefits are difficult to monetise, the variation in physical measures of change can be used to inform policy.

   In terms of increasing the extent of woodland created, more woodland will not lead to higher per hectare carbon sequestration rates or air pollutant removal rates. While the total benefit will increase, £/hectare values will not change with the size of woodland area created.

5) **Where values of natural capital benefits vary by location, these differences can be very large.** For air quality, recreation and physical health benefits, values are calculated at a Welsh local authority level (see Annex 1). As mentioned previously, values are significantly higher where the relevant habitat is located close to urban, densely populated areas. The extent of this variation is greatest for air quality; the value of air quality benefits in Cardiff is estimated to be up to 100 times greater than in Powys. Excluding Cardiff, the benefit value of air quality in Newport is around 50 times greater than Powys. For recreation and physical health benefits, the values are 50 to 60 times greater in Cardiff than in Powys, and up to 10 times greater in Newport.[7]

[7] Since the discounting assumptions are consistent between Welsh local authorities, the factor of variation between local authorities is consistent across time periods of assessment.

Table 2: Benefit-level assessment of location, spatial variation and timescale variation associated with targeted payments

Benefit	**Basis for targeting payments**		**Where would targeted payments generate the highest benefits?**	**Can unit benefits (£/ha) vary with spatial scale (or combination) of action? What is the size of variability of benefit values?**	**Do unit benefits (£/ha) vary with timescale (or combination) of action? What is the size of variability of benefit values?**
	By location in Wales? (i.e., region/local authority)	*By action and habitat (or land use) type?*			
Atmospheric carbon reduction	No. Valuation measure is not specific to location; the benefit from carbon reduction is the same for anybody regardless of where the action is taken.	Yes. Specific new habitats remove carbon from the atmosphere. Certain actions also limit the release of methane emissions (e.g., gully blocking in peatlands).	Small difference. Higher in South West Wales, Lower in North West Wales	No. Values for carbon sequestration per ha of new woodland creation are not a function of spatial scale; the value of one unit of carbon removed from the atmosphere is the same for society regardless of where it takes place. The only variation spatially relates to existing habitats, choice of species for planting (given incumbent soil health), and appropriateness of planting e.g., restrictions in the UA layer to plant on peat).	Yes. Both carbon sequestration rates, and values of carbon removal, vary across time. Annualised PV of per hectare benefit increases as the period of assessment increases. The economic evidence indicates that the annualised present value is over 7 times greater than when calculated over 75 years (£468 per ha) compared to 5 years (£64 per ha), and nearly 3 times greater compared to 10 years (£166 per ha). The size of this variation over time is dependent on assumptions regarding a) increases in carbon sequestration as the woodland matures, and b) the social cost of carbon per ton of carbon sequestered. Standard assumptions indicate that sequestration rates increase linearly until maturity, which is assumed in year 40. From year 40 onwards, maximum sequestration rates remain the same. Carbon values increase over time to reflect societal preferences for carbon removal. These are based on Department for Business and Trade (DBT) projected estimates of marginal abatement costs of carbon emission reductions in the UK from 2020. This is calculated (per tCO_2-e) to increase over time.
Reduction in carbon emissions from agriculture	No. As above, valuation is not specific to location.	Yes. Benefit specific to stocking restrictions.	Yes. Mid and West Wales and South West Wales	Yes. Values may change depend on the level of reduction of stocking density which is spatially variable (see Annex 5). £/tCO_2e unlikely to change, and actions to deliver this benefit will likely deliver other spatially relevant benefits (e.g., water quality).	No. Benefits likely to appear quite quickly and remain constant over time in comparison with baseline livestock emissions.

Benefit	Basis for targeting payments		Where would targeted payments generate the highest benefits?	Can unit benefits (£/ha) vary with spatial scale (or combination) of action? What is the size of variability of benefit values?	Do unit benefits (£/ha) vary with timescale (or combination) of action? What is the size of variability of benefit values?
	By location in Wales? (i.e., region/local authority)	*By action and habitat (or land use) type?*			
Improvements in water quality	Yes, small difference. Some evidence of spatial variation in values between different regions in Wales, although the differences are small. Size of variation across catchments is estimated to be up to two times greater for Tidal Dee management catchment than South West Wales.	Yes. It depends on catchment scale actions and the hydrology of the farmland and surrounding habitat (e.g., buffer/riparian zones).	**No significant difference**	Yes. Evidence of preferences for water quality indicates preferences are stronger (i.e., values are higher) for increases in the quality of local water bodies.	No. There is no economic evidence to suggest that preferences vary across time. Any changes over time will be linked to site-specific variation in physical flows of nutrients into watercourses.
Improvements in air quality	Yes. Valuation is based on local population and pollution levels in a given local authority. Annualised values of pollutant removal benefit in highly urbanised areas (e.g., Cardiff) are estimated to be a factor of 50 to 100 times higher than areas with low population density.	Yes. The model is based on removal from vegetation (e.g., creation of new woodland).	Small difference. Higher in South Wales Central, Lower in Mid Wales and North West Wales.	No. The quantity of pollutant removed per ha does not vary with the size of woodland area.	Yes. As with carbon sequestration, pollutant removal increases as the woodland matures. This may also improve with better management, but the impact is expected to be small. Air quality is likely to change over time as other socio-economic factors change (e.g., emissions from transport, other health-related factors). Annualised PV of per hectare benefit increases as the period of assessment increases. Annualised PV75 (£110 per ha averaged across Welsh local authorities) is over 6 times greater than PV5 (£18 per ha averaged across Welsh local authorities), and over 3 times greater than PV10 (£32 per ha averaged across Welsh local authorities).
Reduction in nutrient run off	Yes. Valuation is based on water	Yes. Linked closely to specific actions	Yes. Mid and West Wales and South West	Yes. Benefit values can vary if multiple farms within a given	**Unlikely.**

Benefit	Basis for targeting payments		Where would targeted payments generate the highest benefits?	Can unit benefits (£/ha) vary with spatial scale (or combination) of action? What is the size of variability of benefit values?	Do unit benefits (£/ha) vary with timescale (or combination) of action? What is the size of variability of benefit values?
	By location in Wales? (i.e., region/local authority)	*By action and habitat (or land use) type?*			
	quality or clean-up costs, which are likely to be spatially explicit.	(e.g., reduce livestock density, cover crops).	Wales since linked closely to reducing livestock density.	catchment reduce livestock numbers and therefore water pollution.	
Increase in accessible green space for recreation	**Yes.** More recreational visits to a given site are likely where the site is located close to urban areas. Annualised PV of recreation benefits can be as much as 20 to 50 greater in population dense areas.	**Yes.** But evidence is less robust for different habitat types and their quality. Variety across habitat types may be more important than a specific habitat types.	**High** – South Wales Central	**Yes,** although there could be either increasing or diminishing returns (i.e., changes in net benefits) to scale when creating newly accessible green space and sites, depending on comparative size and location of suitable substitute recreation sites.	**Possibly but no robust evidence.** There is no robust evidence to profile changes in recreation over time and it is therefore assumed that the number of visitors to a given site in baseline remains constant over time.
Improvements in physical health	**Yes.** This benefit follows recreation opportunities since physical health benefit is based on 'active' recreation visits. Annualised present values of physical health benefits can be as much as 5 to 20 times greater in population dense areas.	**No.** Unless there is variation between physical health activities and habitat types.	**High** – South Wales Central	**Yes.** See recreation, which provides the basis upon which physical health benefits are derived from nature.	**Possibly but no robust evidence.** See recreation.
Flood risk management	**Yes.** It can be based on residential and	**Yes,** due to influence of actions upstream and interaction with	**Likely Yes.** 35% of properties at risk of flooding in Wales are in	**Partially.** Actions over a larger area in a catchment are more likely to have a benefit in terms of reducing	**Depends on the actions.** Some actions will reduce waterflow immediately and this benefit will remain

Benefit	Basis for targeting payments		Where would targeted payments generate the highest benefits?	Can unit benefits (£/ha) vary with spatial scale (or combination) of action? What is the size of variability of benefit values?	Do unit benefits (£/ha) vary with timescale (or combination) of action? What is the size of variability of benefit values?
	By location in Wales? (i.e., region/local authority)	*By action and habitat (or land use) type?*			
	commercial property damages avoided. Flooding will impact downstream communities, and the value of reducing risk to them varies with location.	other land use in the catchment, as well as hydrological catchment characteristics.	the South Central region; the remaining 40% in South East and the South West. Not clear however how the risks and associated damages from flooding would change with upstream management actions.	downstream flood risk. However, most evidence is modelled for smaller catchments (<1km).	constant; other actions will have larger changes in impact over time.
Biodiversity	**No.** There is some evidence that individuals have similar preferences for biodiversity locally, nationally and globally.	**Yes – moderate.** There is some evidence that individual preferences for improvements in condition and existence of certain habitats and the charismatic species within these are greater than for other habitats.	**Not clear from data** whether habitat condition is systematically degraded in certain locations of Wales. Possible correlation with certain land use types (e.g., high-intensity grazing).	**Yes.** Larger areas of habitat are more resilient to external pressures. Where connectivity is enhanced and buffer management is improved, this encourages the passage and transfer of species between (and within) habitats, improving resilience and genetic diversity.	**Yes.** Creation or conversion to new habitats is likely to change the species composition of the habitat and this is likely to be a process which spans several decades in some cases.
Improvements in Water supply	**Yes.** It can be based on varying supply and demand of water abstracted across Welsh localities (i.e., Water Resource Zones), it can be based on the purpose of water use (e.g., public water supply, agriculture,	**Yes.** Geographic and natural features affecting abundance of surface and groundwater are also factors in determining the supply of water available for abstraction and use.	**Likely Yes.** Risks of water scarcity are assessed to be greatest in the South Central (SEWCUS and Tywi Gower Water Resource Zones (WRZs)) and North West (Lleyn/Harlech/Barmouth	**Yes.** Actions over a larger area in the catchment are likely to have an impact on water abstraction potential within a catchment. This may vary within the catchment itself.	**No.** While annual values of water abstracted vary over time, the value of water supply provision for a given use would in theory remain constant. Benefits could vary in the future due to climate change, but significant research would be needed to establish if evidence is available to assess this.

Benefit	Basis for targeting payments		Where would targeted payments generate the highest benefits?	Can unit benefits (£/ha) vary with spatial scale (or combination) of action? What is the size of variability of benefit values?	Do unit benefits (£/ha) vary with timescale (or combination) of action? What is the size of variability of benefit values?
	By location in Wales? (i.e., region/local authority)	*By action and habitat (or land use) type?*			
	electricity generation).		and Blaenau Ffestiniog WRZs). Not clear whether risks to scarcity of water supply would change with environmental actions in these locations.		

4.3 Application of natural capital benefit value to the Universal Actions layer

This section looks at the benefits delivered by Universal Actions (UA) proposed under the universal layer and compares these with the estimated costs and income forgone of delivering these actions. The following four UA heading categories are assessed:

- Creation of semi-natural habitats to meet minimum threshold coverage of 10% (Moxey et al., 2022; Thomson and Moxey, 2023);
- Reduction in livestock density arising from stocking restrictions on existing non-SSSI habitats.
- Creation of new woodland habitat to achieve minimum coverage of 10%; and
- Management and maintenance of existing non-SSSI habitats (semi-natural and woodland habitats) where additional stocking restrictions are not required.

Creation and management of semi-natural and woodland habitats can be delivered through a significant range of activities and actions. The benefits and costs of these actions are likely to be site specific and depend upon various environmental (e.g., current ecological function) and socio-economic (e.g., baseline management actions) factors. The following analysis is based on a landscape-wide average assessment to inform broad scale policy assessment and implementation, whilst still recognising local (and necessary) variation in outcomes and management.

Table 3 to Table 6 describe how natural capital benefits may be delivered by each of the four UA categories. The tables describe:

- Which natural capital benefits are delivered by each proposed UA category;
- Estimated costs of these actions, split by the average farm (across all farm types) and dairy farms) including forgone income. Costs are presented from the 25th percentile farm (i.e., the farm which incurs costs in excess of the lowest cost 25% of full-time Welsh farms), median farm, and 80th percentile farm (i.e., the farm which incurs costs in excess of the lowest cost 80% of full-time Welsh farms);
- The significance of the value of each benefit; and
- The expected timescales over which the benefits can be delivered.

Note that Table 6 does not include cost estimates since there is not expected to be significant income forgone in retention and maintenance of existing habitats and production is generally not being displaced (Thomson and Moxey, 2023). The values are much smaller and less variable across farm and activity type (£35 to £111 per hectare).

Colour Key:

- Green = Evidence of natural capital benefits delivered by SFS actions
- Yellow = Limited or mixed evidence of natural capital evidence delivered by SFS actions
- Red = Evidence of either a) no natural capital benefit, or b) natural capital disbenefit from SFS actions
- Green box = natural capital benefit value is either a) comparatively higher than other natural capital benefits delivered by the same SFS action, or b) delivered in a shorter timescale than other natural capital benefits
- Amber box = natural capital benefit value is either a) comparatively lower than other natural capital benefits delivered by the same SFS action, or b) delivered over longer timescales than other natural capital benefit values

Table 3: Natural capital benefit value analysis of the universal action "Create a minimum of 10% semi-natural habitat" by benefit

<table>
<tr><th>Benefits assessed</th><th colspan="2">Does the action deliver these natural capital benefits?</th><th>Comparative significance of benefit</th><th>Relative timing of benefits delivery</th></tr>
<tr><td>Carbon regulation or emission reduction</td><td colspan="2">Possible with grassland and soil carbon sequestration.</td><td rowspan="2">Carbon benefits likely to be a large proportion of value (£/ha) where stocking is reduced.</td><td>Unlikely to be an immediate benefit but £/ha/yr will scale over time and become more significant in future years.</td></tr>
<tr><td>Reduction in carbon emissions from agriculture</td><td colspan="2">Yes if stocking is reduced.</td><td>Likely to be an immediate short-term benefit.</td></tr>
<tr><td>Air quality</td><td colspan="4">Unlikely to be significant</td></tr>
<tr><td>Water quality</td><td colspan="2" rowspan="6">Likely yes. Reduces risk of livestock being a source of pollution, and introduces greater habitat variety that will reduce the quantity, speed and variety of pollutants within runoff, this will benefit:
Water quality: With higher benefits where creation of semi-natural habitat reduces stocking.
Flood risk management: benefits or disbenefits (e.g., increased runoff from smoother grassland) possible depending on hydrology and type of intervention.
Water supply: depending on location of actions in comparison with abstraction points. Cost reduction likely if it reduces stocking density and clean-up costs.
Possibly for recreation and physical health if adequate access to site facilitates recreation and physical health benefits.

Higher benefits from biodiversity and recreation if it leads to greater habitat diversity in accessible green space or from increase in charismatic species (but likely to be over the long-term).</td><td rowspan="6">Benefits for water quality, water supply and biodiversity expected, with possibility of recreation and physical health benefit. Difficult to value or quantify (physically) at small or broad scales of action.</td><td rowspan="6">Immediate benefits are expected where a) there is access to the habitat for recreation and b) creation of habitat reduces stocking density (therefore reducing run off and costs of clean up). Longer term benefits for biodiversity, flood risk management and water supply.</td></tr>
<tr><td>Recreation</td></tr>
<tr><td>Physical health</td></tr>
<tr><td>Flood risk management</td></tr>
<tr><td>Biodiversity</td></tr>
<tr><td>Water supply</td></tr>
<tr><td>Estimated range of action costs incurred and income forgone (£/ha/yr)
(Thomson and Moxey, 2023)
– see Annex 5 for full data</td><td>All farms (full-time farms only)

25th percentile: £0
Median: £130
80th percentile: £565</td><td>Dairy farms

25th percentile: £249
Median: £646
80th percentile: £947</td><td colspan="2"></td></tr>
</table>

Table 4: Natural capital benefit value analysis of the universal action "Stocking density reduction" by benefit

Universal actions	***Does the action deliver these natural capital benefits?***		**Comparative significance of benefit**	**Relative timing of benefits delivery**
Carbon regulation or emission reduction	***N/A***			
Reduction in carbon emissions from agriculture	***Yes***		Carbon benefits likely to be a large proportion of value (£/ha).	Likely to be an immediate short-term benefit.
Air quality	***Possible*** small benefit from reduction in ammonia emissions from livestock			
Water quality **Recreation** **Physical health** **Flood risk management** **Biodiversity** **Water supply**	**Yes** – Reduces risk of livestock being a source of pollutants, benefiting water quality and water supply. Impacts on biodiversity likely to also be high with removal of intense grazing pressure.		Benefits for water quality, water supply and biodiversity expected, but difficult to value or quantify robustly.	Immediate benefits expected for water quality and supply. Long-term implications for biodiversity.
Estimated range of action costs incurred and income forgone (£/ha/yr) **(**Thomson and Moxey, 2023) – see Annex 5 for full data	**All farms (full-time farms only)** 25th percentile: £16 Median: £93 80th percentile: £287	**Dairy farms** 25th percentile: £381 Median: £632 80th percentile: £980		

Table 5: Natural capital benefit value analysis of the universal action “Woodland creation” by benefit

Universal actions	***Does the action deliver these natural capital benefits?***	**Comparative significance of benefit**	**Relative timing of benefits delivery**
Carbon regulation or emission reduction	***Yes.*** Where woodland removes more carbon from atmosphere than released via respiration, fire or harvest, it is a net sink of carbon which is a significant benefit to society. Care should be taken not to plant on permanent grassland and soils with high carbon stocks.	Becomes a very significant benefit in future years, but lower £/ha/yr value in early years.	Value increases over time. Sequestration rates (tCO_2-e/ha/yr) vary over time when establishing woodland.
Reduction in carbon emissions from agriculture	***No.*** Due to sequencing of UA, livestock has already been reduced before woodland creation actions take place.		
Air quality	***Yes.*** Vegetation from woodland removes air pollutants from the atmosphere, benefiting nearby human populations.	Becomes more significant in future years (less significant than carbon), but lower £/ha/yr value in early years.	Value and physical removal of pollutants increases over time.
Recreation and physical health	***Yes*** if access is provided and management supports visitors to the woodland.	Recreation and physical health likely to be the largest benefits in early years since benefits can manifest immediately if access to property available.	Recreation and physical health benefits are immediate and not assumed to change over time.
Biodiversity	***Likely yes.***	Other benefits (e.g., biodiversity and water supply) may be difficult to value or quantify robustly at a local farm scale.	Benefits for biodiversity are likely to manifest over longer timescales.
Flood risk management	***Maybe*** depending on hydrology of land, where the trees are planted and catchment-scale factors.		
Water quality			
Water supply			
Estimated range of action costs incurred and income forgone (£/ha/yr) (Thomson and Moxey, 2023) – see Annex 5 for full data	**All farms (full-time farms only)** 25th percentile: £98 Median: £196 80th percentile: £536	**Dairy farms** 25th percentile: £444 Median: £763 80th percentile: £1,310	

Table 6: Natural capital benefit value analysis of the universal action “Management and maintenance of woodland and semi-natural habitats” by benefit.

<table>
<tr><th>Universal actions</th><th>Does the action deliver these natural capital benefits</th><th>Comparative significance of benefit</th><th>Relative timing of benefits delivery</th></tr>
<tr><td>Carbon regulation or emission reduction</td><td>Unclear. If condition of woodland, grassland or soils increases carbon sequestration potential (p/ha of habitat), then benefits from management are possible. Some burning practices may result in loss of soil organic matter and emissions.</td><td>Unclear whether additional per hectare carbon sequestration benefits from management will be significant.</td><td rowspan="4">Any additional benefits are likely to manifest over longer time scales since:
• Carbon sequestration (and storage of sequestered carbon) and air quality benefits increase over time, in particular in early age of woodland structure;
• Biodiversity benefits generally manifest over long timescales, but removal of pressures (e.g., scrub clearance, elimination of invasive non-native species) is likely to bring forward some benefits; and
• Recreation and physical health benefits likely over longer timescales since they are linked to recovery and numbers of specific species (e.g., charismatic bird species).</td></tr>
<tr><td>Air quality</td><td>Unclear whether improvement in woodland management practices would improve capacity for pollutant removal. Air quality benefits unlikely from semi-natural habitats under management.</td><td>Unclear whether additional per hectare carbon sequestration benefits from management will be significant.</td></tr>
<tr><td>Biodiversity</td><td>Likely Yes. Clearance of scrub and invasive vegetation to manage semi-natural habitats also likely to deliver benefits for specific species and vegetation structure across a given area. Management of deer also likely to improve biodiversity in a given habitat.</td><td>Biodiversity value is likely to be significant but difficult to value or quantify robustly at a local farm scale, either in isolation or as part of a connected habitat landscape.</td></tr>
<tr><td>Recreation and physical health</td><td>Likely Yes. Where biodiversity increases and management actions improve quality, or provide new, access to existing habitat possible.</td><td>Recreation and physical health benefits are likely to increase in woodland management for biodiversity (in particular bird species) but little evidence to quantify.</td></tr>
<tr><td>Flood risk management</td><td>Mixed evidence. Possible negative implications if excess woody debris is removed, which may increase speed of run off and reduce interception. Burning may increase soil erosion and increase incidence of flooding events. Benefits from restoring (e.g., rewetting) peatland in upper catchments, reducing stormwater volume and increasing groundwater discharge.</td><td rowspan="3">Benefits for flood risk management, water quality and water supply may be significant, but are a) catchment and location-specific, b) difficult to quantity, and c) likely dependent on collaborative actions between connected farm units.</td><td rowspan="3">Woodland management may impact water flow and nutrient interception either immediately or slowly over time depending on the time of action and hydrological/topological profile of the farm and catchment.</td></tr>
<tr><td>Water quality</td><td>Mixed evidence. Not all woodland provides this benefit. If trees do provide water quality benefits (e.g., intercepting nutrient run-off) then it is unclear if better management increases this benefit. Possible negative implications if run off interception reduced due to removal of woody debris. Burning may help maintain low nutrient thereby reducing the impact of run-off. Fertiliser application is lower in grasslands managed for biodiversity.</td></tr>
<tr><td>Water supply</td><td>Mixed evidence. See water quality and flood risk management.</td></tr>
</table>

From the data summarised in Table 3 to Table 6, the following issues are of particular note:

Firstly, **each SFS action delivers *multiple* natural capital benefits (or disbenefits).** Creation of semi-natural habitats may generate benefits for soil carbon in grassland and reduce emissions from livestock if it reduces stock numbers. Reduction in livestock numbers will reduce carbon emissions and nutrient run-off, creating benefits for water quality and supply, as well as biodiversity. Under-grazing through elimination of grazing pressure can have harmful impacts on biodiversity and other ecosystem functions (Keenleyside et al., 2019), so this must be balanced carefully depending on the habitat and landscape characteristics. Recreation and physical health benefits may arise if appropriate access is granted and created habitat is located near urban or populated rural areas.

Woodland creation will deliver significant carbon sequestration and pollutant removal benefits from the new vegetation. Depending on the location and tree species of woodland planted, it may also deliver flood risk benefits, improved recreation and physical health benefits, and benefits for biodiversity.

The maintenance and retention of woodland and semi-natural habitats delivers *additional* natural capital benefits where management activities improve the flow of ecosystem services relative to an assumed baseline of no maintenance of existing habitats. Increases in air quality and carbon sequestration services as a result of woodland management are expected to be relatively low but will arise where woodland loss (i.e., deforestation) would otherwise have occurred (Matthews, 2020; Prosser, 2022). Woodland management could increase provision of biodiversity or water quality/supply benefits, but these are location and/or catchment specific, dependent on the specific objectives of management, management history and the habitat condition pre-SFS action. The same is likely true of recreation and physical health benefits, but there is little evidence in this regard.

Some broad landscape conclusions can however be drawn from previous ERAMMP research (Keenleyside et al., 2019):

- Approximately 40% of woodland is currently not under management. It is not known what proportion of this relates to farm woodland, but nonetheless farm woodland is understood to be at risk of decline in extent and condition when left unmanaged, as well as the impact of invasive species, pests and disease, and climate change.
- These risks impact all natural capital benefits but, in particular, biodiversity, species composition and ecological resilience.
- Management of woodland and semi-natural habitats can be designed to improve species richness and resilience to climate change, control the spread of invasive and/or non-native species, and enhance habitat connectivity.
- Creation of new habitat, planned to connect fragmented parcels of existing habitat, will complement the benefits from improvement management practices for biodiversity and reduce risks of further declines in farm woodland extent and quality.
- Improved biodiversity, in particular of bird populations or charismatic species, is likely to generate recreation and associated physical health benefits.
- Catchment scale benefits (e.g., flood risk management, water quality and supply benefits) increase with landscape scale uptake of management practices designed to achieve these outcomes. In other words, environmental outcomes from management

actions on a single farm unit are likely influenced by management action (or inaction) on adjacent farms.

Secondly, **the natural capital benefits are delivered by UA over different timescales.** Some benefits are delivered reasonably quickly e.g., improvements in water quality arising from actions (habitat creation or maintenance of existing habitat) which reduce run-off and pollution. Similarly, recreation benefits (and therefore physical health) may arise quickly if located close to a user population and is easy to access. In contrast, other benefits occur over longer timescales (e.g., carbon sequestration and pollutant removal from new woodland created, or changes in species composition, both of which increase as woodland matures).

To illustrate the significant influence of timescales on the levels of social value, Figure 1 below demonstrates how the annualised present value per hectare of carbon sequestration, air quality, physical health and recreation change over different time periods for woodland creation. Note that the physical health, recreation and air quality values are averaged across Welsh local authorities.

This shows that in the early years, physical health and recreation are comparatively the largest of the four benefits. This arises under the assumption that access to the recreation opportunity is immediate and there is no (or a minimal) lag in recreation uptake.

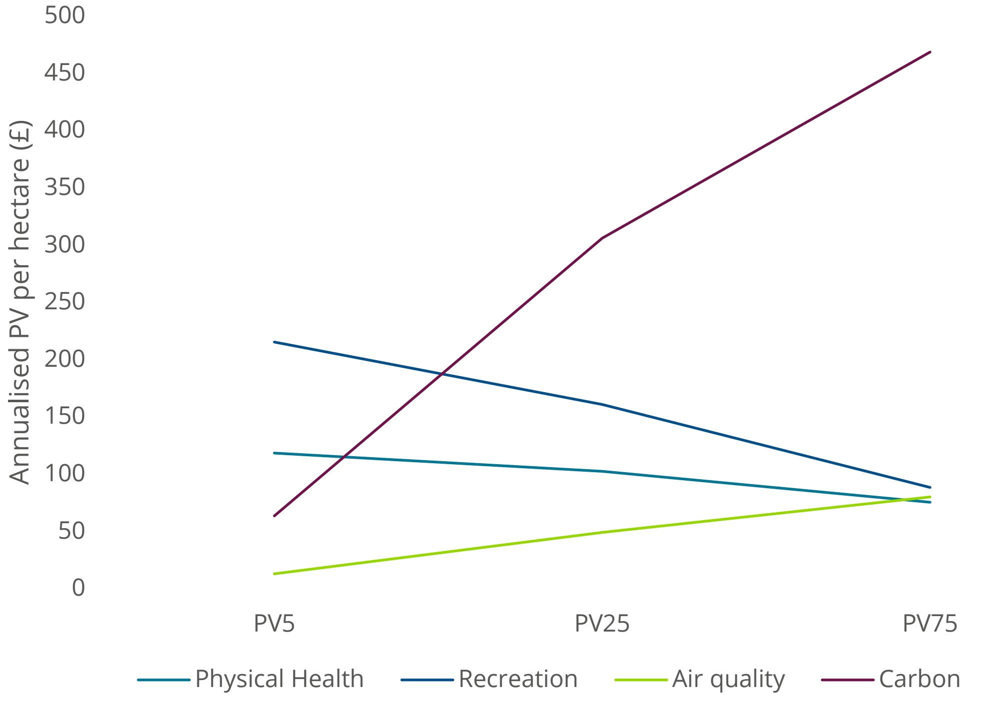

Figure 1: Change in annualised PV per hectare of selected natural capital benefits (physical health, recreation, air quality and carbon benefits) between years 5, 25 and 75 (£, 2022 prices; 3.5% discount rate reducing to 3% from year 31 for recreation and carbon, 1.5% discount rate reducing to 1.29% from year 31 for air quality and physical health)

In comparison, carbon sequestration and air quality benefits are low in the early years after woodland planting. The values for air quality will be even lower if the woodland is created in a more remote location (see Annex 1).

The annual values of recreation and physical health fall over time. This is because the physical flow of benefits (e.g., number of individuals receiving the health benefit from recreation annually) is assumed to be the same in year 75 as in year 5, and the benefits are discounted over time. This may be a conservative estimate (also noting that there are demographic variables, such as population change), but visitor numbers could either increase (e.g., with maturation of woodland and passage or nesting of charismatic species) or decrease (e.g., where users visit alternative sites which are created or improved nearby).

In contrast, the annual present values of carbon and air quality rise over time. This is because the increase in benefits (i.e., the value of the social cost of carbon and avoided health costs) delivered as the woodland matures outweighs the effects of discounting. Not only is the value of carbon sequestration higher, but it rises over time as the social cost of carbon rises over time. This explains the steep incline and therefore the significant proportion of total benefits over a 75-year period attributed to carbon. In comparison, the avoided medical costs used to calculate air quality benefits do not change over time, hence the slower rate of increase (i.e., the increase in pollutant removed by mature vegetation drives the increase in value to society). However, this may be a conservative estimate as medical costs could increase over time with an aging population.

The slope of the rise in annualised value of carbon benefits is also a function of management (e.g., continuous canopy cover versus agro- or silvo-forestry) activities and species (e.g., conifer species sequester more carbon in early years, but aged broadleaf species retain and store more carbon over their lifetime. For the purpose of this analysis, the average carbon sequestration rate across species and age of woodland has been used. This is calculated from a five-year average aggregate carbon sequestration in the UK between 2015 and 2019 , divided by the woodland habitat extent. To align with the calculation of air quality benefits (see Annex 1), carbon sequestration is assumed to increase linearly over forty years until the average carbon sequestration rate is reached. From year 40 until year 75, the UK average carbon sequestration rate is assumed. Planting for different purposes (e.g., fast growth species to achieve the sale of carbon credits) may deliver larger value of benefits sooner.

The rate of change in the mix of annual benefit values between year 5, 25 and 75 will not be the same in all local authorities in Wales. This is illustrated by Figure 2 and Figure 3. Where the local authority has higher population density, creation of accessible woodland is anticipated to generate a higher proportion of immediate recreation and health benefit (e.g., Cardiff) than in rural local authorities with lower population density (e.g., Powys) in the short-term (a five-year assessment).

Over 25 years, the mix of benefits changes compared to the short-term, with carbon and air quality benefits providing a greater proportion of the total benefit. The change in value is greater for high density urban populations than rural local authorities.

In contrast, the spatial variation of the value of carbon sequestration is a function of habitat creation potential. In areas adjacent to higher populations, recreation, health and air quality benefits are higher, so the relative value of carbon sequestration is lower than rural areas.

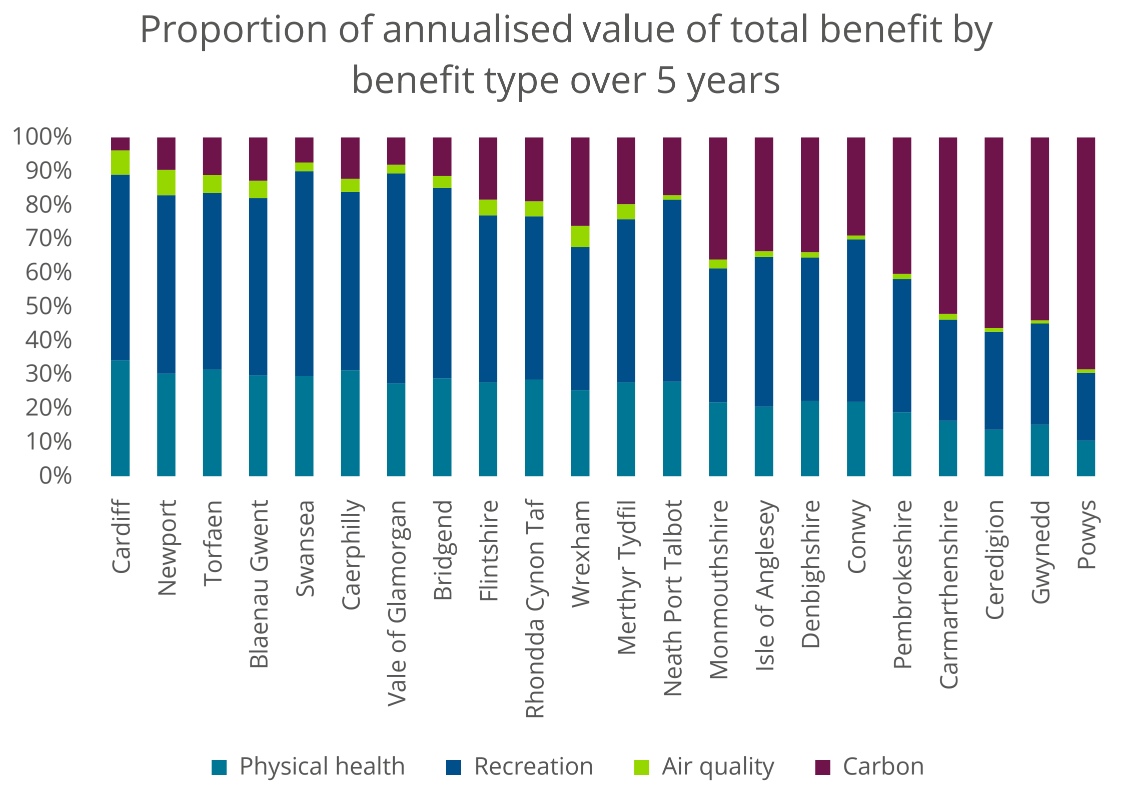

Figure 2: Proportion of annualised value of total benefit by benefit type over 5 years by Welsh local authority

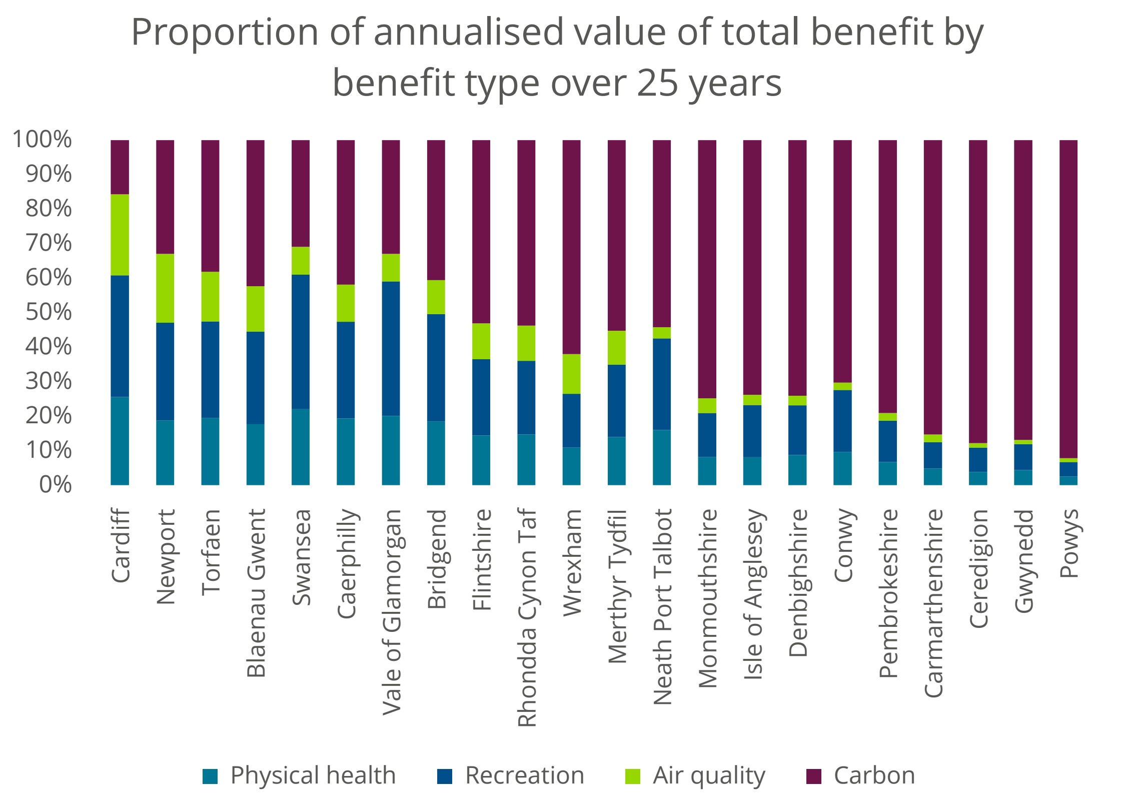

Figure 3: Proportion of annualised value of total benefit by benefit type over 25 years by Welsh local authority

Finally, there is a significant range in estimated costs and income forgone of actions for farmers (Thomson and Moxey, 2023)**. These are also likely to vary spatially due to variation in cost and income forgone between existing land use.** Costs incurred includes costs of management actions required to deliver SFS outcomes, whereas income forgone refers to the loss of output revenue because of having fewer animals and/or land in production. Costs incurred may include cash costs (actual expenditure) or experienced in-kind costs, diverting existing resources to other uses and representing an opportunity cost. Jointly using estimated costs incurred and income forgone from management actions is a common method for estimating compliance costs for setting payment rates.

Table A5.1 to Table A5.9 show the estimated costs and income forgone arising from SFS actions under the UA layer. The estimated costs and income forgone are particularly high for dairy farmers, but there is significant variation within farm type (i.e., the distribution of income forgone across Welsh dairy farms) and between farm types (i.e., distribution across arable, dairy, and other land use types):

- For farms required to create new semi-natural habitat, income forgone (mean value) is estimated to be 8 to 9 times higher for dairy farms than beef and sheep farms. Income forgone for arable farms is estimated to be 3 times higher than the mean value of all farms and 13 to 15 times higher than cattle and sheep farms.

- For farms required to create new woodland, income forgone (mean value) is estimated to be 5 to 7 times higher for dairy farms than beef and sheep farms. Income forgone for arable farms is estimated to be 2 times higher than the mean value of all farms and 4 to 6 times higher than cattle and sheep farms.

Since there is significant variation in expected income forgone from livestock management which would be required under the UA layer, there is likely spatial variation in the value of carbon benefits from reducing livestock given the current distribution of dairy farm locations across Wales. In simple terms, variation in farm types across regions will mean that income forgone will vary across catchments and local authorities.

Finally, cost and income forgone estimated presented do not explicitly consider when the cost or income forgone is incurred. The cost and income forgone data assessed are annualised undiscounted per hectare estimates, which hide temporal variation in particular between capital and maintenance costs for habitat creation. This is particularly important when assessing value for money of SFS actions since a) the majority of habitat creation costs relate to capital expenditure in the first years of the creation project, b) since these costs are incurred sooner in the future, they will be discounted less, and c) benefits from natural processes increase over time as a function of habitat growth and maturation (see earlier in this Section).

4.4 Evaluation of risks of varying payment rates by value evidence

This section discusses the risks with incorporating natural capital values into payments to farmers across several dimensions, including:

- Data accuracy and availability, and

- Risks of double counting.

The section builds on the previous section by characteristics of the data and benefit methodologies which are critical for understanding the risks and uncertainties associated with including natural capital benefit values in payments to farmers.

4.4.1 Data accuracy and availability

The different models and data sources that generate the evidence used in this report have different levels of accuracy. Overall, they are considered robust to support the results and interpretation reported. This is particularly the case for including values in policy appraisal, evaluation or accounting.

However, their use in payment rates should, as for all modelling, allow for the following factors. The accuracy of predictions generated by the Farmscoper tool (which models **nutrient runoff**) depends on how the results will be used.

- If the purpose is to stimulate discussions with stakeholders, then the results for a specific area should be sufficient, regardless of the confidence level in the census data or the appropriateness of other assumptions within Farmscoper.

- Each catchment has been assigned a confidence rating for the agricultural census data in Farmscoper Upscale. For catchments with low confidence, the reliability of other data and assumptions (such as fertiliser rates, timings, and method implementation rates) is also questionable, as indicated in the provided tables and figures (see Annex 1).

- If the confidence in the census data is low for a particular catchment, it might be more suitable to run individual farms within that catchment instead of running Farmscoper Upscale for the entire catchment and its neighbouring catchments. In such cases, data directly usable in Farmscoper Create can be obtained from farmers, or the farm data from Farmscoper Upscale (found in the 'Farm Results' sheet after processing the census data) can be adjusted based on expert opinions.

With respect to **carbon** figures, the accuracy and availability of the data is good. Valuation methods are recommended by The Green Book (HM Treasury, 2022) and typically used in policy evaluation, appraisal and accounting within government. Carbon sequestration and emissions rates are generally robust even though variation exists due to habitat condition and other localised ecological factors (e.g., species and age of woodland). There is likely a sufficient level of evidence available to target payments based on existing habitats, their condition, and appropriateness of new habitat.

With regards to **water quality**, the NWEBS values (Metcalfe et al., 2012; NERA Economic Consulting, 2007) are less robust due to the age of the data[8], nature of the value (i.e., willingness to pay estimates generated from a survey) and the benefit itself. However, the figures are often used in appraisal and evaluation and may be suitable for inclusion in payment schemes. It is notable that for this older data, annual values per kilometre (or kilometre squared) are not as high as for air quality and carbon in particular, so the impact of inclusion may be less significant.

[8] Note that these unit values are currently in the process of being updated.

The eftec and UKCEH (2019) model for **air quality** (specifically for $PM_{2.5}$) is robust and generates values at the local authority level. At very localised scales, robust modelling of air quality service becomes more challenging. The effects of vegetation on air quality can depend upon species composition. Payments would have to be designed around local authority values which are robust in reflecting where vegetation delivers the largest benefits across Wales, but do not reflect even finer scale local variation in values.

With respect to **recreation and physical health,** the data describes general trends in recreation demand and visitor activity (e.g., greater values attributed to areas of high population density), but has some limitations as discussed in Section 4.3 and further in Annex 1. For example, the assumptions of average condition across a given habitat type understates benefits from sites in good condition and overstates benefits attributed to poorly managed sites.

Both data availability and accuracy suitable for valuation of the remaining benefits (i.e., water supply, biodiversity, and flood risk management) is low. This is described below:

- The data accuracy and availability of **flood risk management** benefits from farm-scale actions is variable. The majority of data available is very fine scale (<1km) evidence and with detailed modelling. There is very little empirical evidence on the effectiveness of actions to reduce flood risk at a wider, large catchments, and there is limited valuation evidence suitable for inclusion in payment rates.

- Regarding **biodiversity**, there is no single, universal metric for biodiversity which is spatially distinct. The economic studies review (see Annex 1) considers various aspects of nature, including charismatic and non-charismatic species, and sense of place and experience. Other measures also include connectivity, species fitness and quantity (or proportion) of invasive non-native species. Valuation methods are also uncertain but, whilst trends appear in values (£/household/year), these are less robust than carbon and air quality modelling and very sensitive to assumptions.

- **Water supply** benefits are primarily informed by historic water abstraction data (at the Wales level) available through Defra and Environment Agency/Natural Resources Wales planning tables for each Water Resource Zone. This includes data on supply of water as well as demand, broken down by household and non-household consumption. Whilst there is clearly spatial variation in where demand and supply of water takes place, a detailed, spatially-explicit breakdown of either the costs of water abstraction by Water Resource Zone, or the benefits to water supply from habitat creation and management, are not easily estimated from publicly available data (although this is available for England by EA regional charge area). Such data may exist within Welsh Water's business planning processes, and this could be explored as a source of information to inform targeting of payments.

Whilst the monetary values for flood risk management, biodiversity and water supply benefits are unlikely to be suitable for including directly in payment rates, they are important SFS objectives and there is a risk that linking per hectare payment rates to robust valuation evidence alone disincentivises key SFS outcomes for those benefits which are difficult to measure. This could be mitigated by incentivising actions under the SFS which deliver multiple benefits. Previous work on logic chains (Dickie and Neupauer, 2020), as shown in Table 7, outlined the synergistic relationship between SFS outcomes. Many of these are positive e.g., actions to improve air quality (e.g., new woodland creation):

- Are likely to increase carbon sequestration benefits and, depending on farm type and actions required under the universal layer, will reduce enteric fermentation by reducing livestock density, and
- Will contribute to flood risk management at a small scale, may improve recreation opportunities and therefore positive physical health impacts, and could contribute to the conservation or recovery of biodiversity.

These synergies will depend on selecting actions which can generate multiple benefits, and important considerations include appropriateness of location, coordination across the landscape, the costs of actions and the value of benefits. Whilst it may be difficult to quantify these and other benefits which are difficult to measure and/or value with high precision across Wales, it remains important from a VfM perspective to design payments which incentivise actions at a range of scales which maximises delivery of a combination of these benefits which are critical to the success of the SFS.

Table 7: Synergies between benefit types delivered by SFS action

Benefit	Air quality	Carbon in woodland	Carbon in livestock	Flood risk mitigation	Water quality	Recreation	Physical health	Biodiversity – direct value	Water supply
Air quality		++	+	+	++	+	+	+	+
Carbon in woodland			+	+	+	++	+	+	+
Carbon in livestock				+	++	N	N	+	+
Flood risk mitigation					++	N	N	+	++
Water quality						++	+	+	+
Recreation							++	+	N
Physical health								N	N
Biodiversity – direct value									N
Water supply									

Source: Adapted from Dickie and Neupauer (2019, 2020)
Notes: Synergies are recorded on the following scale: None (N), Synergy (+), Major synergy (++). Blank cells in the bottom half of the table directly mirror those in the top half of the table.

4.4.2 Risks of double counting

Risks of double counting in natural capital benefit values arise where different valuation methods or evidence capture multiple types of benefits of a public good (referred to as "bundles") and these are not mutually exclusive to one benefit type. Risks of double counting arise when:

- The values of more than one natural capital benefit capture the same type of benefit;
- It is not possible to disaggregate these common types of benefits from the benefit valued;
- These values are subsequently added together; and
- These values are used in public policy analyses which are undertaken to inform decision-making (i.e., appraisal, accounting, evaluation or designing payment rates).

For policy design, double counting leads to recommending higher payment rates than the value of the individual benefits delivered by SFS actions. This is because the same types of benefits are included twice or more. This would lead to overpayments for actions by farmers from a natural capital perspective. From the benefits assessed, the risks are considered as follows:

- **There is a low risk of double counting for atmospheric carbon, enteric fermentation from livestock and air quality**. Actions which deliver these benefits could therefore be assessed on the sum of these benefit values.
- **There are some risks associated with adding water quality with other benefit values.** This is because:
    - Water quality values are based on six equally weighted categories:
        1) Fish;
        2) Other animals;
        3) Plant communities;
        4) The clarity of water;
        5) The condition of the river channel and flow of water; and
        6) The safety of water for recreational contact.
    - The above categories *may* overlap with recreation (6), biodiversity (1-3), run-off estimates from Farmscoper (4), and flood risk management (5).
    - This risk can be reduced by only incorporating a subset of the total value for water quality which is not expected to overlap significantly with other benefits. Since each category is assumed to have an equal weighting, one approach is to take one-sixth of the total value. Another approach would be to deduct the overlapping categories from the total value.
- **From an actions perspective, values relating to a reduction in enteric fermentation and nutrient run-off from reducing livestock density will need to be separated for payment purposes.**

Table 8 shows high-level classifications (high/medium/low) which assess factors affecting delivery risks of incorporating natural capital benefit values in payments.

Table 8: Factors affecting policy design risks associated with including natural capital benefit values in payments rates

Benefits assessed	**Factors affecting policy design risk**				
	Data accuracy		*Data availability*		*Double counting*
	Fine scale (farm/local authority)	Broad scale (catchment, region, or country-level)	Small scale (farm/local authority)	Broad scale (catchment, region, or country-level)	Small and broad scale
Atmospheric carbon reduction	***Medium***	***Medium***	***High***	***High***	***Low***
Carbon emissions from livestock	***High***	***Medium***	***Medium***	***Low***	***Medium*** / ***High***
Air quality	***High***	***High***	***High***	***High***	***Low***
Water quality	***Low*** / ***Medium***	***Medium***	***Low***	***Medium***	***High***
Nutrient run off	***Medium***	***Low***	***Medium***	***Low***	***Low***
Recreation	***Medium***	***Medium***	***Medium***	***Medium*** / ***High***	***Low***
Physical health	***Medium***	***Medium***	***Medium***	***Medium*** / ***High***	***Low***
Flood risk management	***Low***	***Low***	***Low*** / ***Medium***	***Low***	***Low***
Biodiversity	***Low***	***Low***	***Low***	***Low***	***High***
Water supply	***Low***	***Low***	***Low*** / ***Medium***	***Medium***	***Low***

5 Conclusions

5.1 Benefit values

The findings above indicate a significant degree of spatial variation in the value of benefits from natural capital, which is supported by the IMP modelling results. This is the case across each of the five benefit types for which there is sufficient valuation:

- In the case of carbon reduction, per hectare values of benefits relating to agriculture, in particular stocking levels, are much greater than those relating to land use change (woodland creation) and wetland (peatland) emissions.

  Given that different habitats and farming practices arise in different regions of Wales, this indicates a strong case for targeting payments to individual farms and sites under the optional and collaborative layers.

- For water quality, there is spatial variation in social values, but the differences are less pronounced than the other benefits. The factors driving spatial variation in water quality are driven by upstream land, farm, and nutrient management, and are expected to generate larger values where pollutants and sediment impact downstream catchments with larger numbers of people.

- There is a strong spatial variation of values for air pollutant removal by new woodland across Wales, with higher values in and around urban areas with higher population density.

- There is an order of magnitude difference between the highest and lowest values of recreation and physical health benefit (between Cardiff and Powys). This clearly demonstrates a strong spatial link between population proximity and density in urban areas and high recreation benefits, and the greater VfM which could be achieved by targeting payments for farm-level actions.

The methodologies for calculating the values of these benefits are generally additive which means that they tend not to double count (i.e., capture benefits twice in two different benefit values). A complex benefit like biodiversity is also part of the natural capital providing other benefits (i.e., it is likely to mediate the delivery of other benefits), so caution is needed to avoid double counting. Risk of double counting will depend on the specific type of benefit of biodiversity being captured in the benefit values. Benefits of species outcomes are fairly distinct from natural capital, but habitat benefits are more closely related to the health of ecosystems providing other benefits, so they are not necessarily additive with other benefit values. Caution should be exercised in using them to design payment rates. Where there are other risks of double counting (e.g., between water quality and recreation, since there is a clear link between the attractiveness of a site of high-water quality for recreation), these risks are known and can be adjusted for.

In aggregate the evidence strongly suggests that there is significant spatial variation in the social value of benefits from natural capital. This significant spatial variation suggests that the majority of these social values cannot be fully realised cost-effectively through single uniform payments across all farms under the Universal Actions. A uniform payment rate risks a) over rewarding actions from farmers which do not generate significant public goods, and/or b) under rewarding the actions from farmers which generate significant benefits to society. These risks are unlikely to be equal, but where carbon benefits are large it is more likely that paying less than the benefit value for actions is the greater risk.

In comparison, there are some benefit types which are likely to be significant but for which there is not robust valuation evidence. Some of these benefits are synergistic. For example, particularly benefits relating to hydrology that are delivered via connected catchments and habitats, in combination with one another. These synergies are highlighted in Table 7. Not only do these benefits arise in combination, but may also be maximised by collaborative actions from adjacent, within-catchment farm units. This has implications for design of payment rates in the optional and collaborative layers, which is discussed in Section 5.4.

The significant variation in social values suggests greater returns could be achieved by targeting payments to where the delivery of benefits is greatest. Although the evidence base is not always ideal to allow targeting, for several benefits (e.g., carbon, air quality, recreation) it is disaggregated in sufficient detail such that payments can be targeted to areas that generate significantly greater (i.e., at least an order of magnitude more) social value from natural capital. The evidence is also sufficient to explain to stakeholders (including land managers) why payment rates for the same management action should differ across Wales.

The IMP modelling further demonstrates the case for targeting higher payment rates under the optional and collaborative layers. Under the 130% Glastir option[9], larger benefits are realised per hectare of land under management – in other words, the higher rates stimulate more farmers, who own land which can provide greater benefits, to join the scheme. This is particularly important for actions which deliver multiple benefit types (e.g., carbon and air quality), and therefore deliver larger value of benefits over time. Some actions may deliver only a single benefit, and perhaps lower value (e.g., water quality only). Where actions provide multiple benefits, payments for these benefits could be targeted under optional actions layer.

The numbers presented look at a 75-year time horizon, but the trends are consistent across a 5- or 25-year period. In some cases, the undiscounted annual benefits (physical and/or monetary) increase as the time horizon increases, but this is not the case for all benefit types.

5.2 Spatial variation in social values

The high spatial variation in the social values of actions delivered under the SFS makes these actions more suited to spatially explicit and targeted payment rates. The reasons for variation in values are different for different benefits, involving a mix of environmental factors (e.g., carbon sequestration or runoff regulation by different habitats) and socio-economic factors (e.g., population density in local area).

These have different implications for payment rate design and targeting. If the basis of variation is environmental- or habitat-based, then targeting can be towards management actions for current areas of habitat, or areas suitable for habitat creation, enhancement, or management, as well as location-specific.

If the basis of variation is socio-economic, then this promotes the case for higher payment rates in specific locations (i.e., to farms close to urban populations). For some benefits,

[9] This is based on modelled outcomes at 130% of Glastir payment rates.

payments will be best targeted through a combination of both management actions and socio-economic locations.

In some cases, values are not expected to vary with the spatial scale of actions taken (i.e., £/hectare does not increase as space covered by SFS action increases) whereas in other cases there is some evidence for this. These are important distinctions because:

- Per hectare social outcomes which increase with the spatial scale of action may be most appropriately targeted in the collaborative action layer. To realise maximum benefits, they are likely to require multiple commitments to SFS action by various farm units.

- Payment rates for such actions will need to strike a balance between the additional societal outcomes from widespread adoption of SFS action and higher payment rates to incentivise uptake. More detailed evidence will be required at variable spatial scales around: a) the impact of land management actions at a landscape scale, b) the difference in social outcomes (in aggregate and per type of farm unit type) of land management actions with different levels of uptake by farm units, and c) likelihood of uptake given a potential range of payment rates.

The value of social outcomes is not just spatially variable, but also changes over time. This can be due to a mix of environmental factors (e.g., time taken for woodland to mature) or socio-economic factors (e.g., the higher value placed on reducing carbon emissions in future). The size and relative values of different benefits from natural capital therefore change over time.

A shorter timescale (e.g., 5 years) increases the relative importance of those benefits delivered immediately. In the case of woodland creation, these are likely to be recreational and physical health benefits for local populations. Over a long time period, benefits increase overall, and air quality and carbon benefits become relatively more important. Benefits for recovery or enhancement of biodiversity will also increase over time, but these are not valued in monetary terms for reasons explained above.

From a social outcomes perspective, the mix of beneficiaries from the public goods delivered by natural capital also changes. In a shorter timescale, the beneficiaries will be those closest in proximity to the SFS actions. Over longer timescales, benefits such as carbon sequestration and biodiversity recovery increase in relative importance. These provide benefits to the wider regional or national population. Although the location of beneficiaries of SFS actions is outside of the scope of this analysis, it is an important consideration for any policy design which uses public money to deliver public goods.

5.3 Universal Actions

Four broad components of the UAs were considered in this report. These were:

- Create a minimum of 10% semi-natural habitat;
- Stocking density reduction;
- Woodland creation; and
- Management and maintenance of woodland and semi-natural habitats.

These actions all deliver different mixes of benefit types, over time and space. Semi-natural habitat creation (if not involving a reduction in livestock density) will deliver largely for benefits which are difficult to monetise. These include flood risk management, water quality, water supply, and biodiversity. Whilst variation of social outcomes across space is likely, the extent of variation for this action is difficult to quantify.

Where a reduction in livestock is involved, a significant proportion of the social value is attributed to the carbon emissions avoided. Evidence from the IMP modelling demonstrates the extent of this (see Annex 1) and the spatial variation of this benefit.

Woodland creation delivers numerous monetised and non-monetised benefits, but the profile of these benefits is different. When considering the short-term benefits, the values of SFS outcomes such as recreation and physical health are comparatively high. When considering the long-term values, the value of carbon sequestration to society increases significantly.

Since the time assessment is a key determinant of the delivery of a given mix of SFS outcomes, it could be considered whether the timing of the payment is altered to match and promote the delivery of certain SFS outcomes. For example, relative to the long-term social benefits from carbon sequestration, it is likely that payments for woodland creation will be front-loaded. This requires a commitment on behalf the of the land manager to manage the land for the purposes of carbon sequestration over a longer period than a typical farm business cycle, but up-front or staggered payments help incentivise this type of action and cover the likely higher up-front creation costs.

Finally, the evidence suggests that there are large variations in the income forgone for different farm types across Wales. As noted in the Thomson and Moxey (2023) SFS economic analysis, this variation is considerable both *between* and *within* farm types. In some cases, mean averages exceed median values, which demonstrates that: a) more farms have lower profile of annual per hectare costs, but also that b) a smaller number of farms have comparatively high costs, which rise steeply. This variation in costs and income forgone will have implications for uptake of the SFS.

5.4 Optional and collaborative actions

This report has not considered specific actions proposed under the optional or collaborative layers. However, the evidence of spatial variation in natural capital values does suggest some principles by which inclusion of social value in payment rates in these layers may be most efficient.

The variation in annualised present values per hectare of air quality, water quality, recreation and physical health benefits across local authorities and water catchments in Wales is significant (see Table 3). These ranges vary by a factor of between two for values in water quality benefits to a factor of 100 for values in air quality (recreation and physical health benefits fall in the middle). Not only do these benefits vary significantly across space, but these variations also generally arise together and are additive. This means that variation of value between local authorities and catchments from SFS actions increases, making a strong case for targeting payment rates to support the delivery of spatially variable bundles of benefits. This is particularly important since different site-level management interventions (and therefore costs of delivery/income forgone) will likely be required to deliver potential environmental outcomes and flexibility in payment rates under the scheme will be needed to support actions which are higher cost.

Whilst the monetary valuation evidence is less robust, there is quantitative evidence in biophysical units which demonstrates how flood risk, water supply and biodiversity benefits vary across space due to the connectivity of habitats and catchment hydrology. More detailed modelling is required at a catchment level to determine social values arising from uptake of SFS actions under the optional or collaborative layers. Currently, the quality of the national evidence is insufficient as a basis to vary payments for these specific environmental outcomes.

Since the variation in social value with sufficiently robust evidence closely correlates with the proximity of habitats delivering the benefit and local beneficiary populations (e.g., densely populated areas), payments rates to deliver actions which generate these benefits in these locations could include an element of social value. This could mean varying payment amounts (i.e., £/hectare/year) for the same actions in different locations in Wales.

Regarding the different scheme layers, social values could be included in payment rates within the optional layer to target actions which a) generate the highest social value in different parts of Wales and where multiple benefits are delivered by management actions, and b) can be delivered by farm units without the need to collaborate with adjacent or upstream farm units. In other words, locations where actions deliver greatest value could justify higher payment rates under the optional layer than locations where feasible environmental actions do not deliver these outcomes.

The evidence reviewed suggests that an example action under the optional layer could be **woodland creation in excess of the minimum coverage of 10% farmland.** Table 5 demonstrates that woodland creation supports air quality, recreation (if the land is accessible) and physical health benefits, each of which varies across space but is not significantly contingent on the actions of adjacent farm units. Payment rates for woodland creation could be higher where they are located in close proximity to beneficiary populations and provide suitable access to support recreation and health benefits.

In comparison, inclusion of social values in payments under the collaborative layer not only requires evidence of spatial variation in values, but also of enhanced environmental outcomes where farm units undertake collaborative and synergistic actions together. This enhancement can arise because social outcomes will be greater if all enter the scheme than if only a few do, and the risks associated with environmental outcome reduce as more farmland enters the scheme. Notably, the types of benefits that are likely to arise under collaborative action (e.g., flood risk management, and water quality and supply) are catchment/ landscape- based benefits. These also arise in bundles (i.e., flood risk, water quality and water supply benefits are often delivered together), which makes a strong initial case for inclusion in payment rates. However, nationally consistent empirical evidence is typically not available at the necessary scales, and the valuation evidence is more uncertain for the benefit types necessary for targeting in payment rates. An alternative approach in this case would be to link higher payment rates to management actions in locations which reduce the downstream risks e.g., from flooding or water scarcity.

5.5 Payment design risks and principles

Different models and data sources generate evidence on social outcomes from SFS actions. These models have different levels of accuracy and data availability, in particular where they involve modelling over time. Many of these values are regularly used in policy appraisal, evaluation or accounting. Inclusion in payment rates is less clear since benefit delivery is often more local in nature than policy appraisal, and the level of data accuracy and availability required is higher.

In general, there is good evidence for inclusion of values for carbon sequestration (and emission reduction), and air pollutant removal in payment rate design. There is high confidence in the factors that cause variability, and those factors can be used to vary payments even in the absence of monetary value evidence. There is medium confidence in the values of recreation, physical health and water quality. However, there is low confidence in the values of other benefit types.

The data analysed in this report have been broken down by spatial units (e.g., per hectare or kilometre value) and time (annual values and present values over 5, 10, 25, 50 and 75 years). These different data inform policy development in different ways. 75-year present values indicate long-term benefits from protecting and enhancing the environment, including benefits to future generations. 5-year present values only capture short-term returns to the current population, and will not capture benefits from environmental enhancements that, while of potentially high value, take longer periods of time to be realised (e.g., as a result of trees needing to mature).

Results are also presented as annualised present values for the 5-, 25- and 75-year time periods. This is calculated by dividing the total PV over the years of the time period.

The costs of many of the actions to deliver benefits from natural capital can be weighted towards the short-term, while benefits are spread over long time periods and can be weighted towards the long-term. This explains the upward trend in air quality and carbon sequestration benefits in Figure 1, alongside recreation and physical health benefits which are highest in the short term.

The annualised present values sit within the range of annual values involved, so can be thought of as splitting the difference in some proportion (not necessarily 50:50) between short-term returns to up-front investment, and longer-term benefit to future generations.

This metric is a good policy fit for payment rates because it balances design risks arising from the variation in natural capital benefits and cost burden over time. This is for the following reasons:

- Firstly, the timing of benefit delivery is variable across benefit type, time and location. Practically speaking, a simple payment rate scheme will therefore have a mismatch between delivery of social value and payment.

- Secondly, there are uncertainties in environmental outcomes, and therefore the delivery of natural capital benefits, arising over time from a given set of actions. These arise in part due to inherent uncertainties in natural processes.

- Thirdly, there are also difficulties measuring and appraising *additional* environmental outcomes from management actions. As mentioned previously, condition and extent of semi-natural and woodland are generally considered poor and declining, and at risk of further degradation from pests and disease, invasive species and climate change. This makes VfM assessments from interventions to manage and maintain existing habitats complicated with broad scale assumptions. For example, whilst the net benefits from management and maintenance may be understated in locations where the condition of existing habitats is worse than the current evidence and data suggests, achieving these benefits may be more costly and require more intensive intervention than previously thought, or the uncertainty associated with these outcomes is higher.

- Finally, in comparison with payments that reflect benefits realised in the year they are made, they avoid larger future spending commitments by the Welsh Government in line with the wording of the Well-being of Future Generations Act (2015). For example, the Welsh Government would need to commit to pay farmers a relatively high payment several decades in the future in order to: a) fully reflect the future benefits of current woodland planting, and (b) incentivise farmers to take action now in return for delayed revenues. They also avoid the liabilities on farmer contracts that would arise if payments were based only on costs of delivery – the Welsh Government could face high transactions costs to ensure that the actions invested in (e.g., woodland planting) were retained over long timescales while they realised their full benefit to society. This would add to scheme administrative costs and could become complex when land ownership changes.

Using annualised present values therefore balances these risks over time and are therefore a potential guide to designing payment rates to farmers that reflect the social values that their actions deliver. This helps farmers plan for current and future actions and increases payment rates in early years where capital costs of habitat creation are higher than ongoing maintenance and management.

A 75-year annualised present value is suggested to best align to the Wellbeing of Future Generations' Act's requirements to consider the needs of future generations. However, it should also be recognised that other factors are important over such timescales (e.g., increasing uncertainty of environmental outcomes with climate change).

In terms of double counting, there are small risks (e.g., between water quality and biodiversity), but overall, the risks of this leading to poor policy design (e.g., overpayment for actions) is low.

Based on the evidence reviewed, the following principles may be applied to targeting payment rates:

- The existence of variation in value across space indicates that fixed rate payments for delivering certain actions which deliver these benefits risks underpaying some farm types, while achieving lower VfM from others.

- Fixed rate payment (£/hectare/year) may be more suitable for actions which deliver:
    - Similar benefit values (regardless of farm type);
    - Benefit mixes which are largely non-monetised; or
    - Actions for which outcomes are not contingent on landscape-scale collaboration.

- Payments should be varied and targeted in the optional and collaborative layers. In particular:
    - Where the delivery of environmental outcomes requires farm-specific and bespoke actions above and beyond those required in the universal layer, these actions should be funded under the optional and/or collaborative layers to facilitate flexibility in achieving the desired outcomes under the SFS.
    - Where benefits vary across space but outcomes from management actions on a given farm unit are not contingent on the management actions of others, these actions and associated payments should be included under the optional layer.
    - Where benefits vary across space, but outcomes are contingent on collaboration between connected farm units, actions and payments should vary under the collaborative layer.
    - Payment rates can still be varied based on a) measured delivery of environmental outcomes, or b) management actions in locations expected (or modelled) to deliver social value even if it is not valued.

- The existence of wide variations in measured social value does not mean that payment rates need to incorporate exact, site-specific values. A simplified approach where social value exceeding a given threshold (e.g., £x per hectare per year) is incorporated into payment rates possibly balances the risks of low uptake in locations where management actions are most likely to deliver high social value with the administrative burden of site-specific appraisal and payment rates.

There is robust evidence that the social value of some benefits from natural capital vary significantly (by orders of magnitude) spatially. The evidence distinguishes between differences in environmental conditions, and differences in the people affected, that drive these variations. It does so at a fine enough scale to inform policy design. This supports the case for varying payment rates in the optional and collaborative layers by matching actions to farms which deliver those benefits to achieve VfM.

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7 Annex 1: Benefit review

This annex presents the project team's findings from the sources reviewed as part of the evidence review. The benefits discussed are:

- Atmospheric carbon reduction
- Water quality
- Air quality
- Recreation
- Physical health
- Flood risk management
- Biodiversity
- Water supply

This annex discusses how the benefits are valued from an economics perspective, how these benefits are delivered physically, and how (or if) the values vary spatially.

Key data tables are included in Annex 2, which provides additional detail.

7.1 Atmospheric carbon reduction

7.1.1 Carbon sequestration and avoided emissions from soil

7.1.1.1 *How the benefit is assessed*

Many habitats sequester carbon at different rates across space and time. The value of carbon sequestered in habitats is estimated using sequestration rates for each habitat (tonnes CO_2-e per hectare) and the non-traded price of carbon (BEIS, 2021). There is a steady upward trend in the monetary value of carbon over time (from a central value of £241 in 2020 to £378 in 2050) to reflect the increasing value to society of reaching carbon reduction goals. The value per tonne is the same for all locations in a given year, so the variation in value is entirely driven by the different impacts of habitats on atmospheric carbon over time. These impacts can be from sequestration into soil, or emissions from carbon stored in the soil.

Table A2.2 shows the per hectare carbon sequestration rates for woodland, arable farmland and grassland. This data demonstrates that sequestration rates vary across habitats, and within habitat types over time e.g., younger woodland sequesters carbon more quickly than established woodland.

Emissions can arise from farming taking place on peat soils, which releases the carbon stored as the peat degrades in condition. If peat is in pristine or near natural condition, the rate of carbon sequestration is significant but is roughly offset by the warming potential of methane emissions (produced under anaerobic conditions by microbes). When farming on peat, however, the rate of emissions increases as the peat becomes exposed to the atmosphere, and potentially eroded and damaged. The UK Peatland Code (IUCN, 2017) provides a useful classification of condition, and establishes a range of greenhouse gas emissions factors for peatland by condition. These rates are also included in Table A2.2.

Spatial variation of carbon reduction value in Wales

Figure 4 shows the range in annualised value of carbon sequestration/emissions per year per hectare over a 75-year period using a 3.5% discount rate for woodland, grassland and farmland. There is a significant range in annualised values for carbon sequestration by woodland, but equally large values associated with losses from farming on peat soils. This range arises because due to both a) different species, and b) different rates at different points in time. From Table A2.2, it is evident that savings from actions which may reduce emissions by improving the condition of peat soil condition could generate significant annual value, of a similar magnitude to the value of carbon sequestration by woodland creation. Detailed data can be found in Table A2.3 in Annex 2.

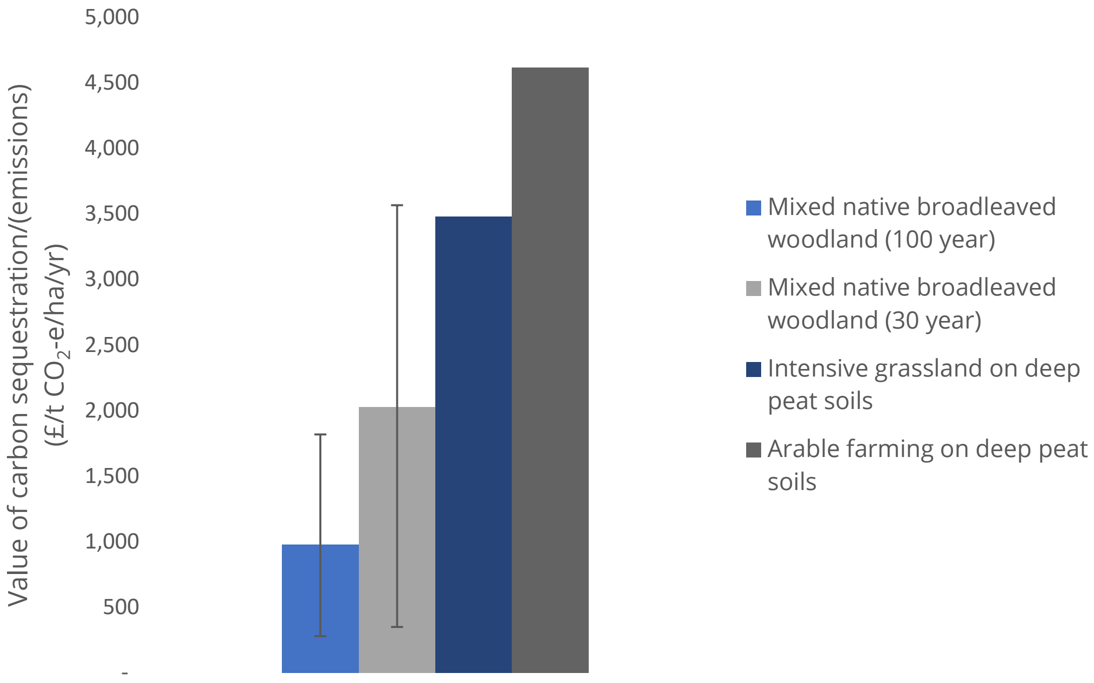

Figure 4: Annualised present value of carbon sequestration/emissions per hectare per year by habitat type and activity (£, 2022 prices, PV75, 3.5% discount rate reducing to 3% from year 31)
Source: eftec analysis

Value differs across space in Wales where a) specific habitats already exists, and b) for habitat creation. For carbon, and other environmental benefits, some locations are more suitable than others for certain management actions that reduce atmospheric carbon (e.g., woodland creation should not take place on peat soils).

Potential Atmospheric Carbon Reduction Values under SFS

Evidence from the IMP modelling runs in 2021 demonstrate the spatial distribution of the value of carbon benefits delivered under the SFS habitat and nutrient management scenarios (SFS3a and SFS3b). Spatial patterns of carbon stock changes are driven by transitions between rotational grass and arable farming. The rates of payment influence the uptake rate of certain management actions, with some action types specifically precluded from modelling (e.g., planting new woodland on peat soils).

In respect of emissions arising from agriculture (see Figure 5 and Figure 6), over a 75-year period, there is not a large variation in the present value of carbon benefits in different regions across Wales under the 100% Glastir payment scenario. Both Mid Wales and the South West generate the largest per hectare values. Under the 130% Glastir scenario, around one-third of the benefits arise in South West of Wales, with smaller per hectare values attributed to South Wales Central and the North West. Detailed data can be found in Table A2.4 in Annex 2.

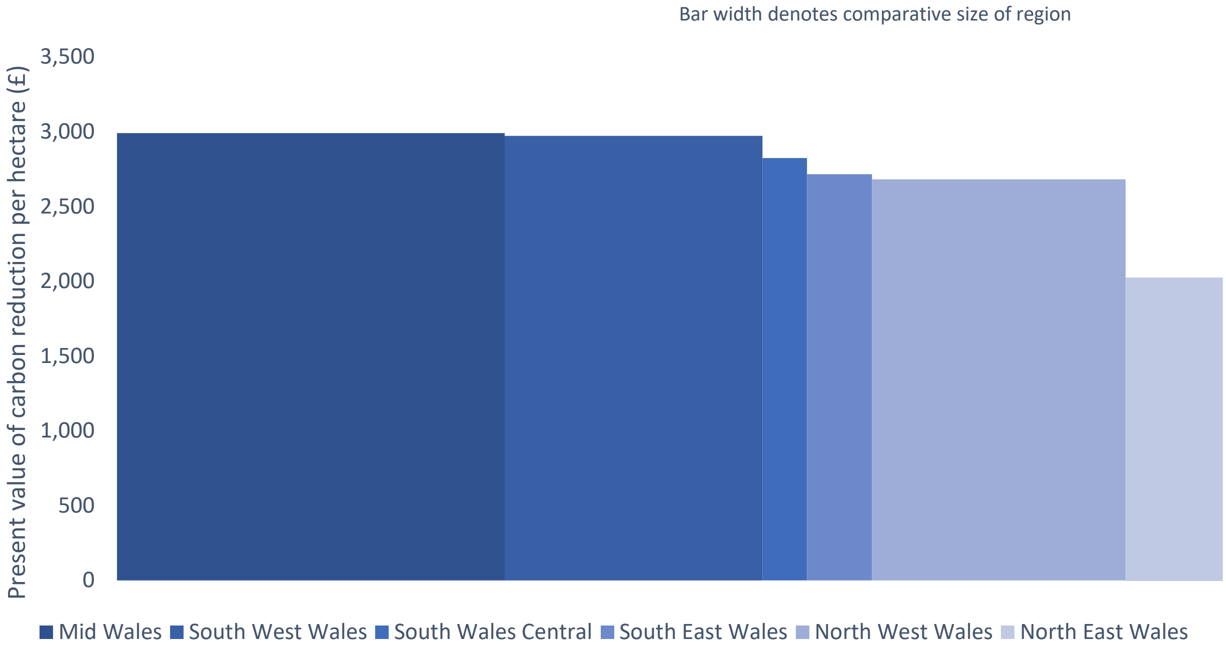

Figure 5: Present value of carbon benefits from agriculture per hectare per year arising under scenario management SF3 10 by Welsh region (£, 2020 prices, PV75, 3.5% discount rate reducing to 3.0% from year 31)
Source: IMP modelling

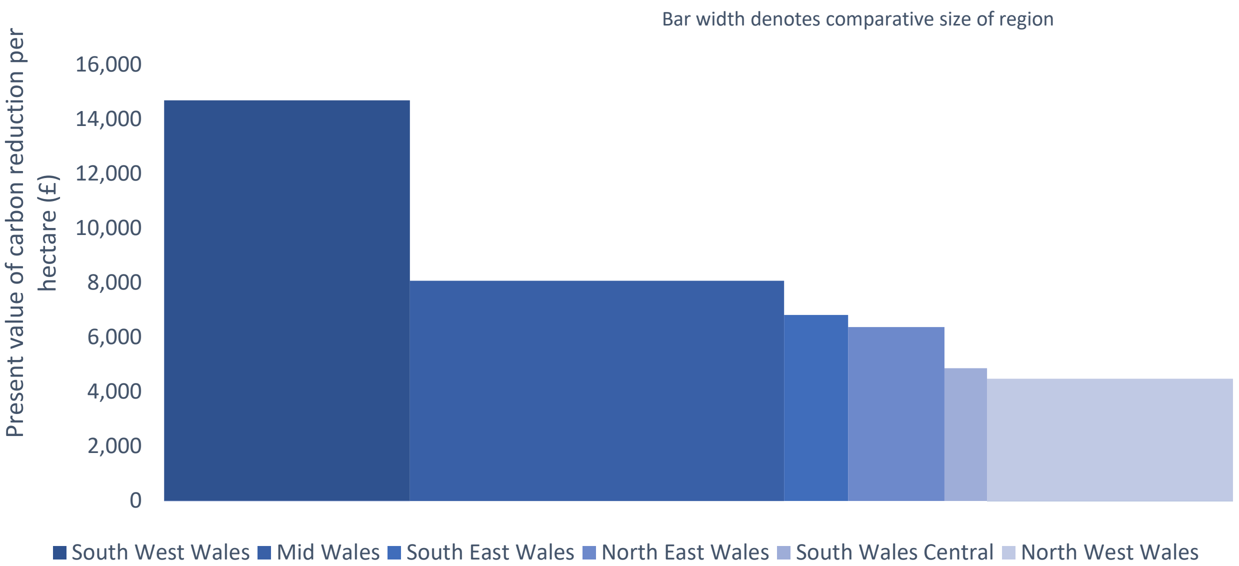

Figure 6: Present value of carbon sequestration from agriculture per hectare per year arising under scenario management SF3 30 by Welsh region (£, 2020 prices, PV75, 3.5% discount rate reducing to 3.0% from year 31)
Source: IMP modelling

This pattern is the same for benefits arising from land use change (e.g., woodland creation) and losses arising from conversion of lowland peatland to arable farming (this is the main driver of the negative value per hectare in the North West of Wales in Figure 7). Where payment size is large enough (e.g., 130% of Glastir), emissions from arable farming on lowland peatland fall as area under this type of farming falls. The South West still generates the largest carbon reduction benefits per hectare. Detailed data can be found in Table A2.5 in Annex 2.

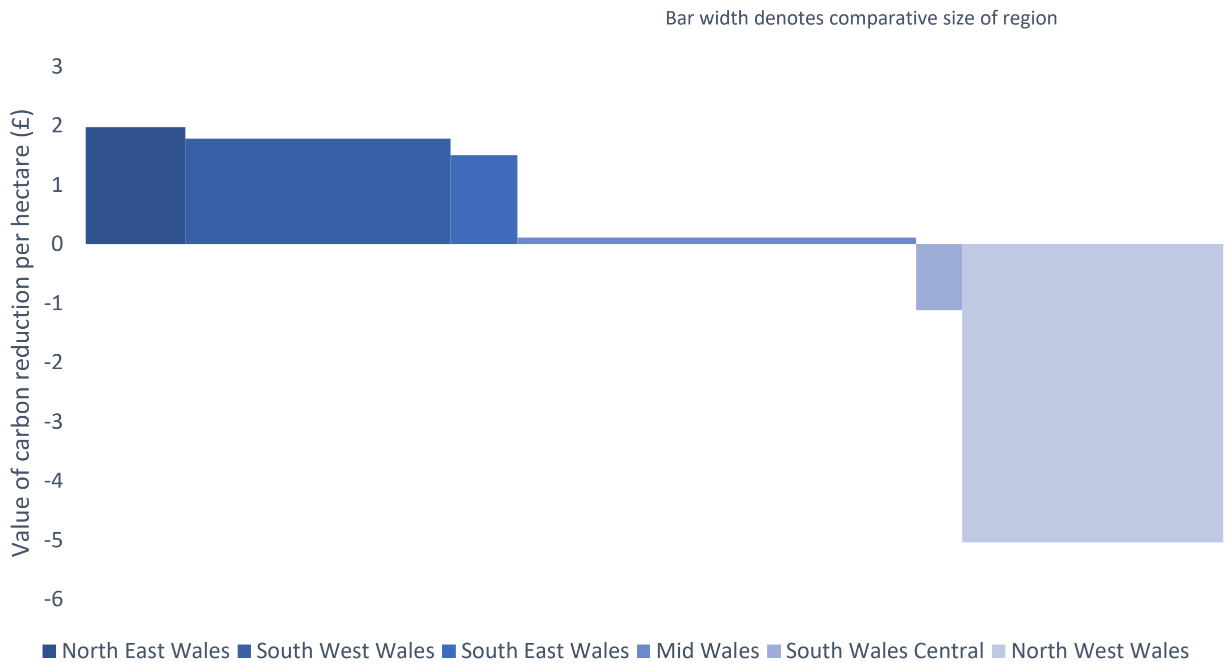

Figure 7: Present value of carbon sequestration from agriculture per hectare per year arising under scenario management SF3 10 from land use change and wetland emission reduction by Welsh region (£, 2020 prices, PV75, 3.5% discount rate reducing to 3.0% from year 31)
Source: IMP modelling

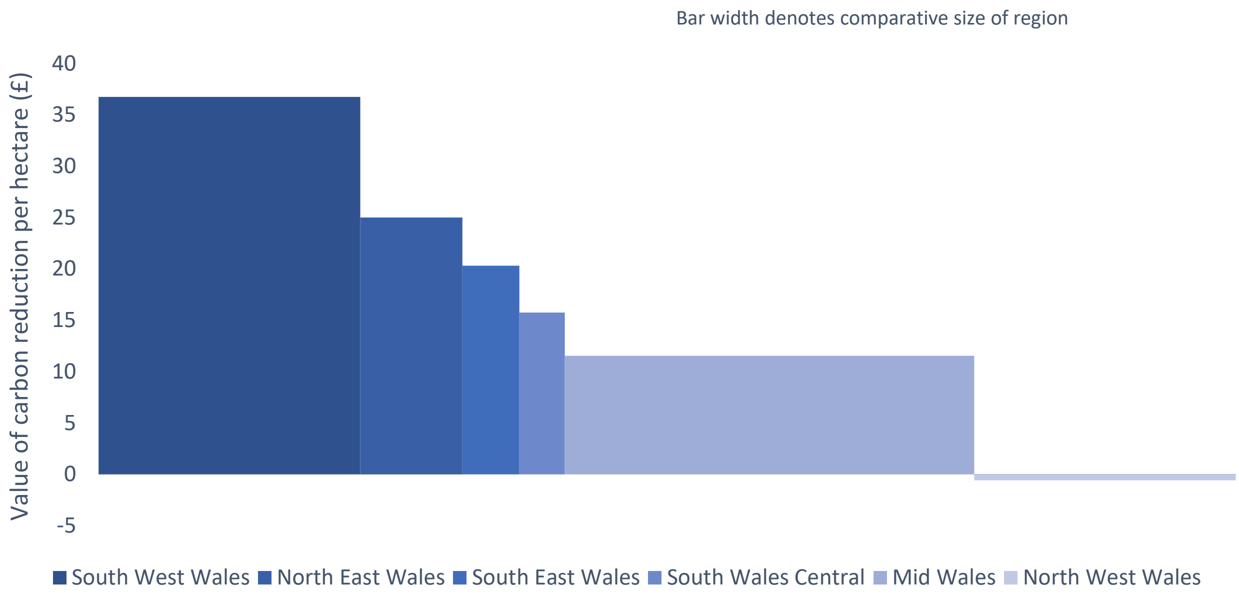

Figure 8: Present value of carbon sequestration from agriculture per hectare per year arising under scenario management SF3 30 from land use change and wetland emission reduction by Welsh region (£, 2020 prices, PV75, discount rate, 3.5% discount rate reducing to 3.0% from year 31)
Source: IMP modelling

7.2 Water quality

7.2.1 Pollutant reductions

7.2.1.1 *How the benefit is assessed*

The key data source reviewed for pollutant reductions was Farmscoper V5[10] and in particular the Farmscoper Evaluate tool. This tool within Farmscoper V5 aims to assess environmental benefits by assigning a monetary value to the reduction of pollutants. To achieve this, the tool calculates the quantity of each pollutant saved in a mitigation scenario compared to the previous situation and multiplies these reductions by a monetary value in pounds (£) per unit for each pollutant. The sum of these values across all pollutants provides the overall assessment. The default values utilised in Farmscoper can be found in Table A2.6, and the sources of this data are described below. It should be noted that, while the tool can consider pesticides and faecal indicator organisms (FIOs), it does not provide default values for these pollutants.

Pollutant losses are provided for soil types and climate zones that are representative of the range of conditions across England and Wales. Six climate zones are defined based upon the range of annual average rainfall across England and Wales for 1961-1990 (Barrow et al., 1993).

Farmscoper predicts energy usage in terms of CO_2-e. Methane and nitrous oxide can be converted to CO_2-e using global warming potentials of 25 and 298, respectively. Therefore, all three pollutants can utilise the greenhouse gas (GHG) figure from Table A2.6. The unit value represents the cost of mitigating GHG emissions and is based on the non-traded cost of carbon (BEIS, 2021).

The value assigned to ammonia is derived from air quality damage costs (Defra, 2020) and primarily accounts for the impacts of air pollution on human health.

The values for nitrate, phosphorus, and sediment are sourced from Defra (2006). This particular study estimated the economic harm caused by water pollutants across various ecosystem goods and services (such as drinking water quality, fishing, bathing water quality, and eutrophication), specifically attributing the contribution of agriculture.

Please note that the referenced reports are from different years, and that the final values incorporated into Farmscoper have been adjusted to reflect a value for 2021 using a GDP deflator.

7.2.1.2 *Spatial variation of pollutant reduction value in Wales*

The following factors influence how the value of environmental benefits (in particular water quality benefits) from reduced pollutants are calculated with Farmscoper V5:

- **Livestock Management:** Farmscoper allows users to enter livestock counts for different categories. If the size or productivity of livestock on a farm differ from the national average, the number of livestock can be adjusted accordingly. The model assumes that cattle are housed for around 6 months and sheep are outdoors for most of the year.

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[10] See here for more details about Farmscoper V5: https://adas.co.uk/services/farmscoper/

- **Fertiliser and Manure Timing:** Data on fertiliser and manure application timing are based on national practices. There is some variation in timing, especially for phosphorus fertiliser, but the impact on pollutant loss is generally small (1 to 5% of total loss).
- **Fertiliser Rates:** Users can specify nitrogen and phosphorus fertiliser application rates. The default values are based on national averages, but there can be variations when comparing with a small number of randomly selected farms.
- **Manure Storage and Spreading:** The model assumes fixed proportions for spreading and storing livestock manure. Different spreading techniques can be accounted for in the model. Manure on arable land is assumed to be incorporated after five days.
- **Soil Phosphorus Status:** Farmscoper allows users to specify the distribution of different Soil Phosphorus indices on their farm. Default values are based on national monitoring data, but regional variations exist. Assigning different concentrations to each index can result in variations in predicted phosphorus losses.
- **Soil Type and Climate Zone:** Users can select one soil type and climate zone for their farm. Results are based on average physical environments derived from models. However, selecting only one soil type to represent the entire farm can be an issue if the farm is atypical compared to others of the same type.
- **Mitigation Method Implementation:** Farmscoper includes a library of mitigation methods. Users need to specify the current implementation of these methods. Default values are based on national survey data, but they may not accurately reflect actual management practices in a specific catchment.

7.2.1.3 *Economic factors which influence variations in value over space and time*

The Cost workbook in Farmscoper V5 provides unit cost data for various agricultural activities such as fertiliser, labour, fencing, and tyres. The data spans from 2010 to 2025, allowing users to select values for specific years or calculate average values over a range of years. The unit costs are categorised as fixed, gross margin, or capital costs, and some mitigation methods may incur costs in multiple categories. For capital costs, the tool displays both the total cash upfront cost and the amortised cost spread over the asset's lifetime.

Each mitigation method in the Cost workbook has one or more worksheets that list the necessary assumptions and associated values for that method. These assumptions are combined to determine the multiplication factors for the relevant unit costs. For example, field length and buffer strip width are used to calculate the area of lost arable production, which is then multiplied by the unit cost for arable gross margin. The tool calculates the sum of capital costs (upfront and annual amortised), fixed costs, and gross margin costs for each method, providing totals by category and overall.

The tool also allows users to specify whether a mitigation method is linked to a manure or nutrient management plan. These plans are costed separately to avoid double counting, as certain high-risk areas for manure application may apply to multiple mitigation methods.

It's important to note that the calculated costs are annual values (excluding upfront capital costs) and do not include payments to farmers from agri-environment schemes or incentives.

To facilitate scalability and application to different farm types and sizes using Farmscoper Evaluate, the tool converts the total operating costs (fixed and gross margin) and amortised capital costs for each method into cost coefficients. These coefficients include:

- **Excreta cost coefficient:** Represents the annual mitigation action cost per cubic meter of livestock excreta produced on a farm. It assumes that the cost is directly proportional to the number of animals and the total excreta production. For example, roofing concrete yards would be proportional to the yard size, which, in turn, corresponds to animal numbers or excreta production.

- **Manure cost coefficient:** Represents the annual mitigation action cost per cubic meter of managed slurry or farmyard manure on a farm. It assumes that the cost reflects additional handling and storage expenses proportional to the quantity of manure. For instance, restrictions on manure application timing may necessitate additional storage facilities.
- **Area cost coefficient:** Represents the annual mitigation action cost per hectare of arable, grass, or rough grazing land on the farm. It assumes that the cost accounts for forgone income or labour proportional to the land area. For example, cultivating compacted soils requires an extra tillage operation.
- **Fertiliser cost coefficient:** Represents the annual mitigation action cost per kilogram of nitrogen or phosphorus fertiliser applied. It assumes that the implementation cost is directly proportional to the original amount of fertiliser used before mitigation. For instance, replacing urea fertiliser with ammonium nitrate would incur a cost based on the amount of urea being replaced.

While several mitigation methods can help farmers save money, mainly through reduced fertiliser use, the tool does not assume that any savings from one method can offset the costs of implementing other methods. Users have the option to disregard cost savings associated with mitigation methods if desired.

Modelling of these factors was used within the IMP model runs that provide some of the data reported and analysed in this section.

7.2.2 Improvement in waterbody status

7.2.2.1 *How the benefit is assessed*

Maintaining the quality of water in the environment has associated welfare benefits to the public. The approach taken to assessing the value of these welfare benefits based on the Water Framework Directive (WFD) quality status of the waterbodies in Wales.

The benefit (or cost) is calculated for a physical change from a given status (i.e., change in the WFD status from Good to Moderate). There are three different physical changes that could arise: bad to poor, poor to moderate, and moderate to good. The economic value is based on the National Water Environment Benefits Survey (NWEBS) values (Metcalfe et al., 2012; NERA Economic Consulting, 2007). The NWEBS values provide low, central, and high estimates of values for coastal and transitional water bodies.

The NWEBS values represent survey respondents' willingness to pay for six equally weighted ecosystem components (Defra, 2015):

- Fish;
- Other animals such as invertebrates;
- Plant communities;
- The clarity of water;
- The condition of the river channel and flow of water; and
- The safety of water for recreational contact.

This assessment uses the central value estimates for avoiding the deterioration of lakes, coastal and transitional water bodies and for rivers in the catchments relevant to Wales. Estimates are produced for lakes (i.e., annual £ value per km^2) and rivers (i.e., annual £ value per km).

Using the central estimates, the total annual value of avoiding the deterioration of the current water quality across all identified water bodies in Wales can be estimated. Evidence regarding the distribution of per kilometre and per square kilometre values is presented below.

The values of water quality are expected to be driven by:

- **Locality of beneficiary** – people tend to value local improvements in water quality more highly than national-scale improvements.
- **Population density** – the population density of a given area is positively correlated with higher values for water quality since more people value the local benefits (e.g., sustaining economic activities and human health).
- **Ecological scope of improvement** – people tend to value improvements to higher quality water body status more than to lower quality water body status (e.g., the value of changing from moderate to higher is greater than the value of change from poor to moderate).

7.2.2.2 *Spatial variation of water quality value in Wales*

With respect to Welsh specific catchments, there is low level of variation in values per kilometre for rivers. The difference in values is not as large as the difference in carbon values (see previous section) across regions; the lowest value (£1,000 per kilometre per year in South West Wales) is less than a factor of two lower than the highest value (£1,800 per kilometre per year in Tidal Dee). The below also demonstrates a weak but negative correlation between the size of the catchment and the annual values (this is noted by the wider bars on the right pertaining to lower value catchments).

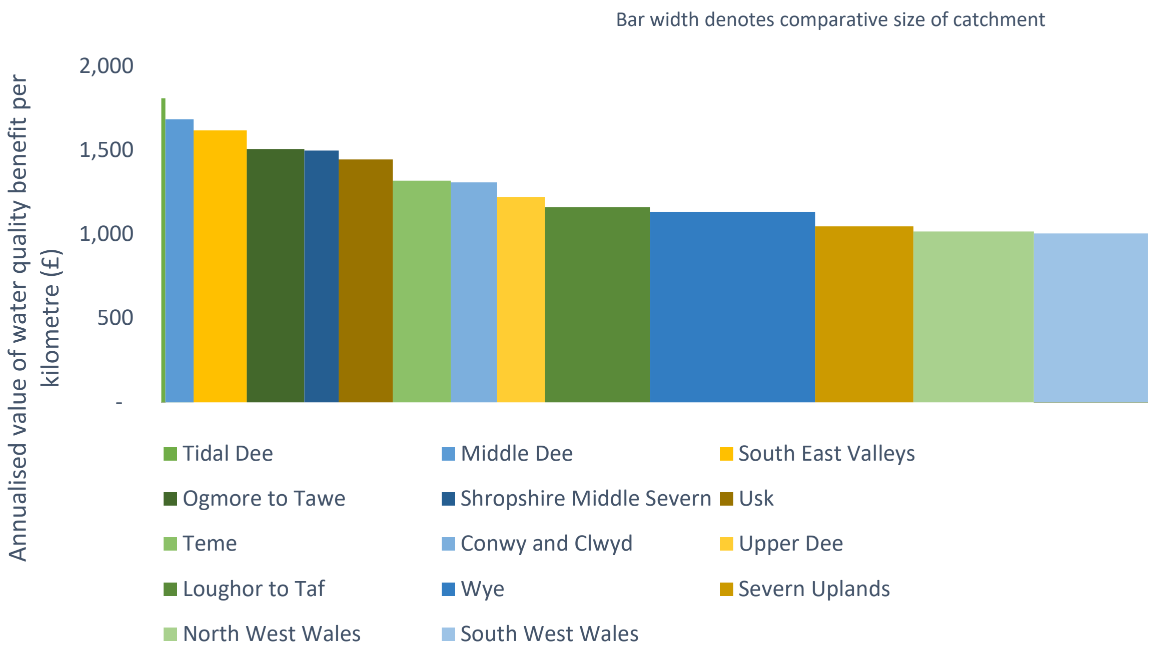

Figure 9: Annualised present value of water quality of rivers per kilometre per year by Welsh catchment (£, 2022 prices, PV75, 3.5% discount rate reducing to 3.0% from year 31)
Source: National Water Environment Benefits Survey (NWEBS) values (Metcalfe et al., 2012; NERA Economic Consulting, 2007)

With respect to the value of the coast, lakes and transitional waters, values are also derived from NWEBS, per square kilometre, for relevant River Basin Districts (RBDs). Figure 10 shows the values per area of lake or water body per annum (in 2022 prices). The values again demonstrate only a small amount of spatial variation, but again show slightly lower values in the West of Wales in comparison with the Eastern RBDs which border England.

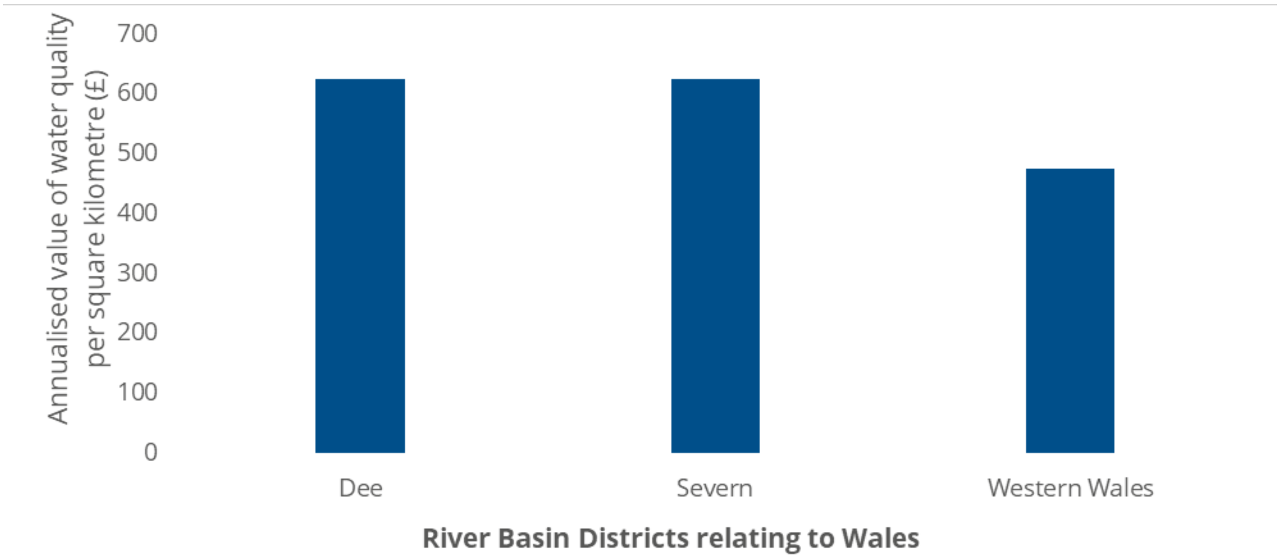

Figure 10: Annualised present value of water quality per square kilometre per year by select river basin district relating to Wales (£, 2022 prices, PV75, 3.5% discount rate reducing to 3.0% from year 31)
Source: National Water Environment Benefits Survey (NWEBS) values (Metcalfe et al., 2012; NERA Economic Consulting, 2007)

7.2.2.3 *Potential Water Quality Improvement Values under SFS*

Evidence from the IMP model in 2021 (see Figure 11 and Figure 12) indicates that there is some level of spatial variation in water quality benefits across Wales. Modelling for water quality is based on the values of the change in status of specific water bodies in Wales under SFS management scenarios and bundles which incentivise managing of nutrient release into rivers. It considers impacts of various pollutants, including non-agricultural source of pollutants, and accounts for the flow of nutrients (nitrogen and phosphate) to downstream catchments and subsequent changes in sediment load.

The benefits arise from reduction in livestock numbers and from cover cropping fixing nitrogen and reducing losses in arable soils. The spatial distribution of these values is uneven, with the majority of these benefits in the North East and South West, both of which generate values much larger than those in the South East and South Wales Central. More catchments are projected to improve the quality of waterbodies under the 130% Glastir option with higher uptake of nutrient management activities. This also improves drinking water quality, although the patterns of improvement are more complex with respect to sediment load.[11]

[11] Some areas reduce sediment load from cover cropping whereas other increase load due to increases in arable and decreases in rotational grass).

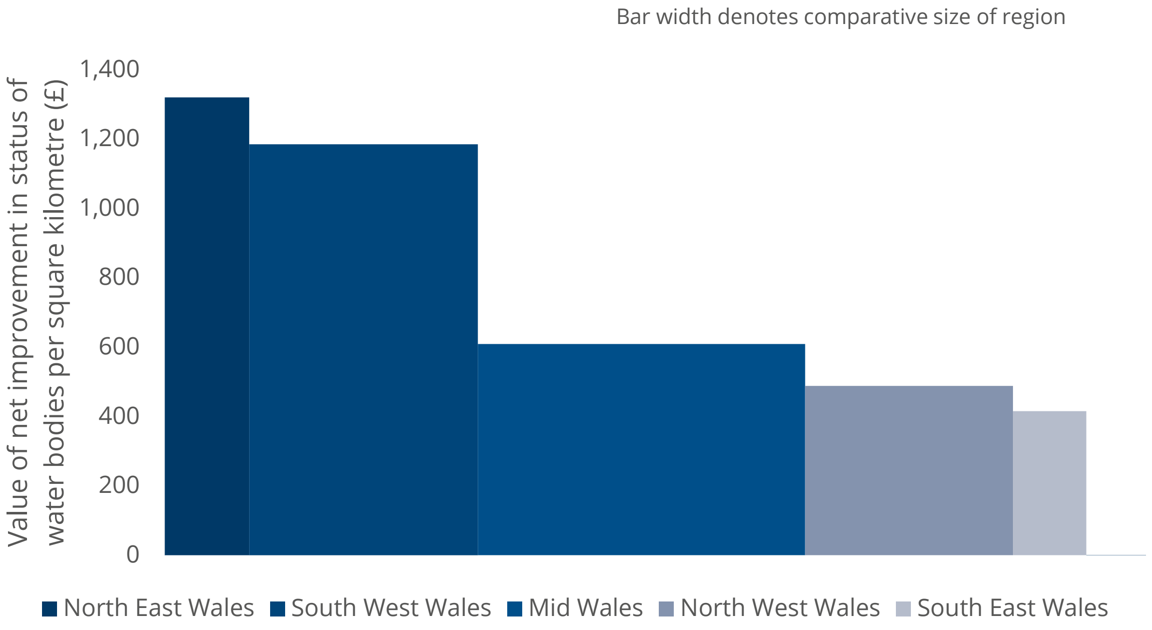

Figure 11: Present value of improvements in water quality per square kilometre per year arising under SFS scenario 3 10 (100% Glastir) by Welsh region (£, 2020 prices, PV75, 3.5% discount rate reducing to 3.0% from year 31)

Source: IMP modelling

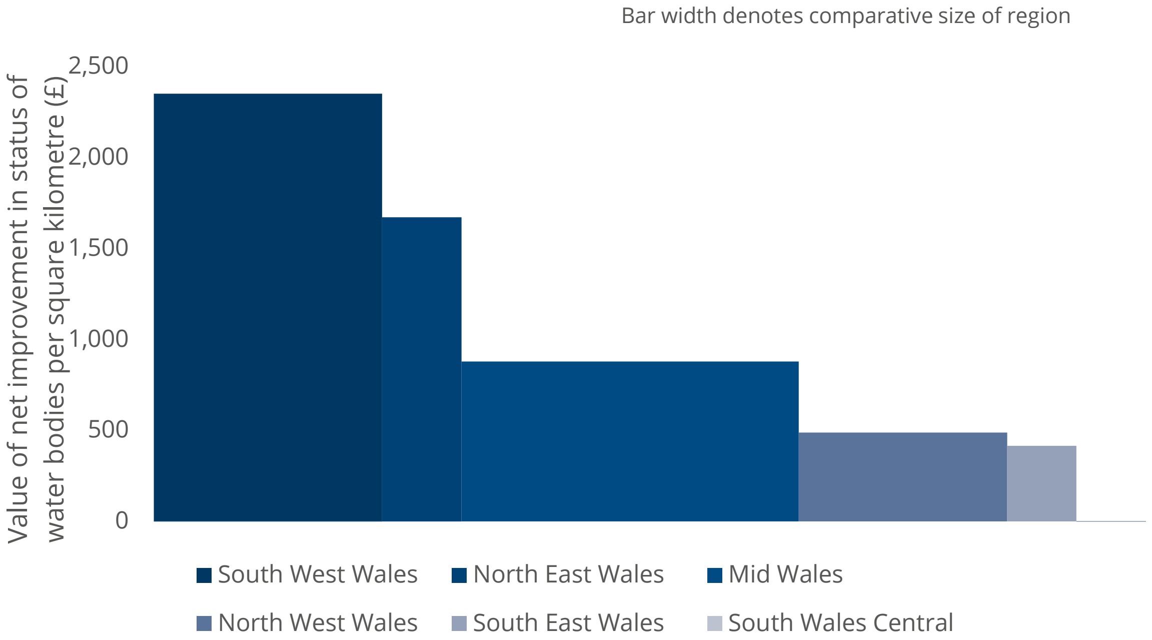

Figure 12: Present value of improvements in water quality per square kilometre per year arising under SFS scenario 3 10 (100% Glastir) by Welsh region (£, 2020 prices, PV75, 3.5% discount rate reducing to 3.0% from year 31)

Source: IMP modelling

7.3 Air quality

7.3.1 Emissions to air

The National Atmospheric Emissions Inventory (NAEI) provides emissions maps of various pollutants on a 1x1 kilometre resolution. Research undertaken by ADAS for the Welsh Government which developed "environmental profiles" for fifteen illustrative farms across Wales used the total emissions from the NAEI, which are built up from several map distributions for each sector, to help derive farm profiles for air quality. The individual sector distributions were developed using information and surrogate statistics appropriate to each sector[12].

For the illustrative farms analysis, each field was attributed with the pollutant values of the 1x1 kilometre cell in which it resided. To provide a farm-level air quality figure, an area weighted mean based on all the fields of each farm was calculated. Air quality is likely to vary throughout the year and depends on multiple factors. Data could be linked with land cover type and farm type to represent impact of different land management practices on quality.

PM_{10}: The illustrative farms analysis reported PM_{10}. This is particulate matter with an aerodynamic diameter of less than 10 micrometres (µm). Recent epidemiological evidence has linked concentrations of particles in the atmosphere with human health effects. The PM_{10} standard was designed to identify those particles likely to be inhaled by humans.

Ammonia, Methane and N_2O: The distributions of ammonia, methane and N_2O emissions from agricultural sources were mapped by the UKCEH. Data from the Agricultural Census for England, Scotland, Wales and Northern Ireland were combined with emission factors for livestock, fertiliser use and UKCEH Land Cover Map 2007 data within the UKCEH model to calculate emissions maps.

The CH_4 maps showed high uncertainty because a large proportion of the emissions (about 44%) are from the agriculture sector which has a high level of uncertainty associated with its emissions. The N_2O maps showed high uncertainty because a large proportion of the emissions (about 80%) are from the agriculture sector which has a high level of uncertainty associated with its emissions. Even though all the data were collected and originally produced outputs of the data in 1x1 kilometre due to non-disclosure constraints, the data were aggregated at 5x5 kilometre resolution. As a result, by evenly distributing the 5x5 kilometre maps in 1x1 kilometre maps, there was a loss in data quality.

Table A1.1 to Table A1.6 show the mean value for emissions by air quality pollutant type across the different illustrative farm profiles.

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[12] This data is based on and includes information from:
Ordnance Survey (GB) data © Crown copyright and database right 2020
Royal Mail (GB) data © Royal Mail copyright and database right 2020
National Statistics (GB) data © Crown copyright and database right 2020
© Crown copyright and database rights 2020 licenced under BEIS's Public Sector Mapping Agreement with Ordnance Survey (licence No. 100037028) and Defra's Public Sector Mapping Agreement with Ordnance Survey (licence No. 100022861).
Tsagatakis, I., Richardson, J., Evangelides, C., Pizzolato, M., Pearson, B., Passant, N. & Otto, A. (2020) UK Spatial Emissions Methodology: A report of the National Atmospheric Emission Inventory 2018. Retrieved from: https://naei.beis.gov.uk/reports/reports?report_id=958

Table A1.1: Example of Air Quality pollutant measures (tonnes/1x1 km) for different illustrative farm profiles: Dairy

Air Quality (t/1x1 km)	**Hill and Upland**	**Dairy: Hill and Upland, <€300k**	**Dairy: Hill and Upland, ≥€300k**	**Lowland**	**Dairy: Lowland, <€350k**	**Dairy: Lowland, ≥€350k**
Pollutant	**Mean Value**					
Ammonia	1.3	1.8	2.2	2.0	2.4	2.6
Methane	10.1	11.6	13.6	13.4	13.6	14.6
Nitrous Oxide	0.3	0.4	0.4	0.5	0.4	0.5
$PM_{2.5}$	0.2	0.3	0.2	0.3	0.3	0.3
PM_{10}	0.3	0.4	0.3	0.5	0.4	0.4

Table A1.2: Air Quality pollutant measures (tonnes/1x1 km) for different illustrative farm profiles: Hill Sheep

Air Quality (t/1x1 km)	**Hill**	**Sheep: Hill, <€70k**	**Sheep: Hill, €70k-€115k**	**Sheep: Hill, ≥€115k**
Pollutant	**Mean Value**			
Ammonia	1.0	0.9	0.8	0.8
Methane	9.0	8.4	7.4	7.3
Nitrous Oxide	0.3	0.3	0.3	0.3
$PM_{2.5}$	0.2	0.2	0.1	0.1
PM_{10}	0.3	0.3	0.2	0.2

Table A1.3: Air Quality pollutant measures (tonnes/1x1 km) for different illustrative farm profiles: Hill Cattle and Sheep

Air Quality (t/1x1 km)	**Hill**	**Cattle and sheep: Hill, <€70k**	**Cattle and sheep: Hill, €70k-€115k**	**Cattle and sheep: Hill, ≥€115k**
Pollutant	**Mean Value**			
Ammonia	1.0	1.0	1.1	1.1
Methane	9.0	10.7	8.9	9.4
Nitrous Oxide	0.3	0.3	0.3	0.3
$PM_{2.5}$	0.2	0.3	0.1	0.1
PM_{10}	0.3	0.4	0.2	0.2

Table A1.4: Air Quality pollutant measures (tonnes/1x1 km) for different illustrative farm profiles: Upland Cattle and Sheep

Air Quality (t/1x1 km)	**Upland**	**Cattle and sheep: Upland, <€70k**	**Cattle and sheep: Upland, €70k-€115k**	**Cattle and sheep: Upland, ≥€115k**
Pollutant	**Mean Value**			
Ammonia	1.8	1.8	1.8	1.6
Methane	11.8	11.6	11.6	11.0
Nitrous Oxide	0.4	0.4	0.4	0.4
$PM_{2.5}$	0.2	0.3	0.3	0.2
PM_{10}	0.4	0.4	0.4	0.2

Table A1.5: Air Quality pollutant measures (tonnes/1x1 km) for different illustrative farm profiles: Lowland Cattle and Sheep

Air Quality (t/1x1 km)	Lowland	Cattle and sheep: Lowland, <€60k	Cattle and sheep: Lowland, ≥€60k
Pollutant	**Mean Value**		
Ammonia	2.0	1.9	1.9
Methane	13.4	13.1	12.6
Nitrous Oxide	0.5	0.5	0.4
$PM_{2.5}$	0.3	0.4	0.2
PM_{10}	0.5	0.5	0.4

Table A1.6: Air Quality pollutant measures (tonnes/1x1 km) for different illustrative farm profiles: Other and All Farms

Air Quality (t/1x1 km)	Other	All Farms
Pollutant	**Mean Value**	
Ammonia	1.6	1.5
Methane	11.2	10.8
Nitrous Oxide	0.4	0.4
$PM_{2.5}$	0.3	0.2
PM_{10}	0.4	0.4

7.3.2 Air pollutant removal

7.3.2.1 *How the benefit is assessed*

Air quality benefits arise from the ability of different types of vegetation to remove pollutants from the air. This benefit is estimated for the amount of $PM_{2.5}$ removed by woodland (which makes up more than 70% of this benefit in the UK (Jones et al., 2017)) and the human health benefits of this removal.

Jones et al., (2017) modelled this benefit for the UK national accounts using data on the variety of different levels of $PM_{2.5}$ concentration, types and extent of vegetation and density of human population across the country. An update to this study has produced estimates of $PM_{2.5}$ removal per hectare of woodland by local authority. The kilograms of $PM_{2.5}$ removed by hectare of woodland (eftec and UKCEH, 2019) is multiplied by the total woodland area in a given local authority in Wales. The $PM_{2.5}$ removal per hectare of mature (i.e., existing) woodland is estimated to be falling over the period of 2015 to 2030 based on the assumption that emissions and concentrations are falling over time.

The economic value of this benefit is estimated as the healthcare cost avoided due to avoided illnesses (eftec and UKCEH, 2019). The value of the benefit as £ per hectare of new woodland (in 2022 prices) for a given local authority is then the healthcare cost avoided multiplied by the total new created woodland area in that local authority.

The eftec and UKCEH (2019) modelling of future benefits declines in line with lower emission / concentrations assumption mentioned above and are discounted using the lower health discount rates (HM Treasury, 2020).

7.3.2.2 *Spatial variation of air quality value in Wales*

The physical quantity of this service hinges on three primary factors:

- The amount of background pollution, notably particulate pollutants.
- The type, amount, and location of vegetation.
- The density of population potentially benefitting from reduced exposure to pollution.

These variations across space are reported in the model from eftec and UKCEH (2019), which reports the value of air pollutant removal in each local authority in the UK. These values are summarised in Figure 13, which shows the annualised value per hectare of air pollutant removal by woodland created. Figure 13 demonstrates the significant spatial variation that arises because of the location of population and urban areas. The value of this benefit has a highly uneven spatial distribution – it is inversely correlated with the size of the local authority but positively correlated with the population density (see Figure 14). The annualised value per hectare can be as high as £800, which equates to a present value to up to £50,000 per hectare over 75 years (see Table A2.5).

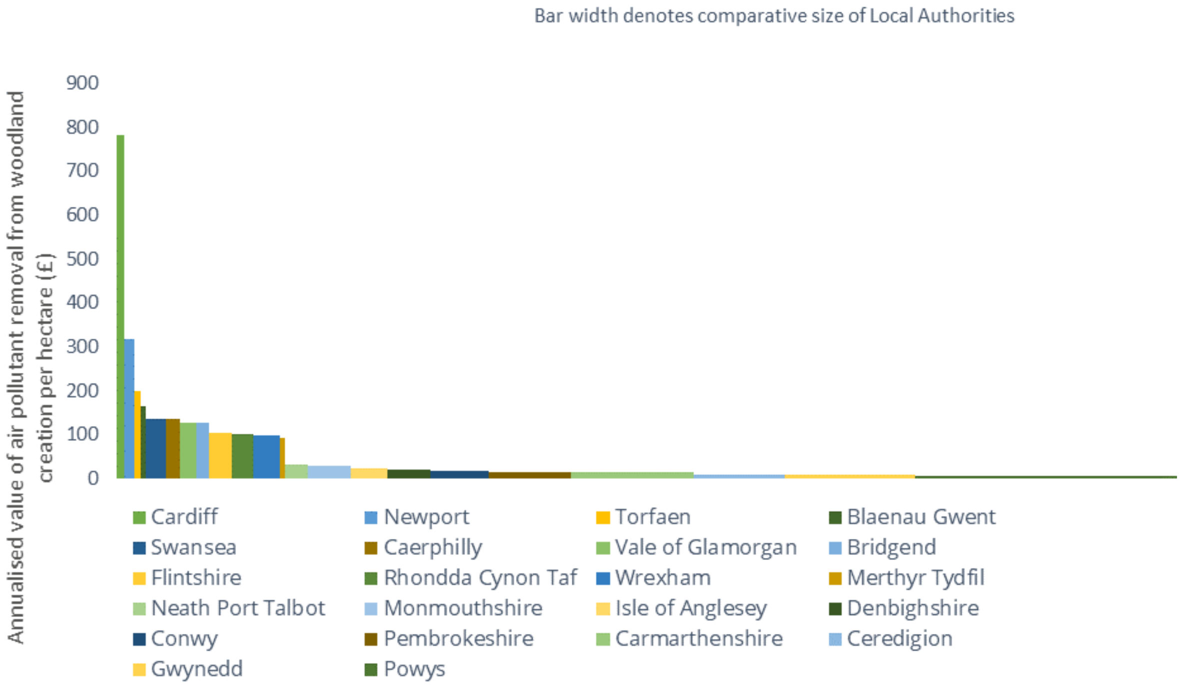

Figure 13: Average present value of air pollutant removal by woodland creation per hectare per year by Welsh local authority (£, 2022 prices, PV75, 1.5% discount rate reducing to 1.29% from year 31)
Source: eftec and UKCEH (2019)

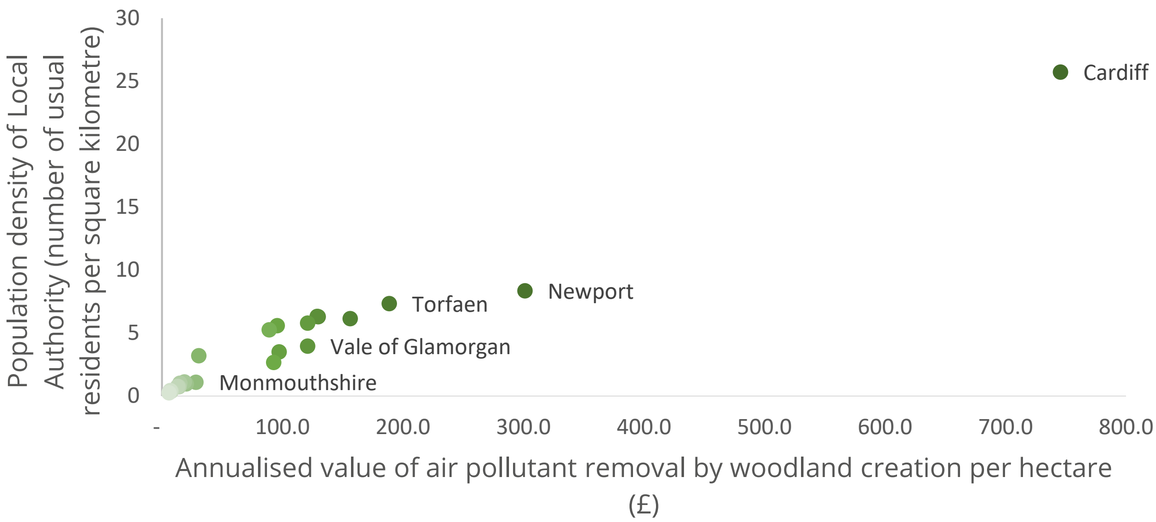

Figure 14: Relationship between value of air pollutant removal by woodland creation and population density across Welsh local authorities
Source: eftec and UKCEH (2019)

7.3.2.3 Potential Air Pollutant Removal Values under SFS

This evidence is supported by the IMP model runs in 2021, reflecting high benefits by woodland creation and hedgerow management in local authorities with higher urban populations and population density (e.g., Cardiff and Bridgend) in South Wales Central. This variation is particularly large – up to a factor of six across both Figure 15 and Figure 16.

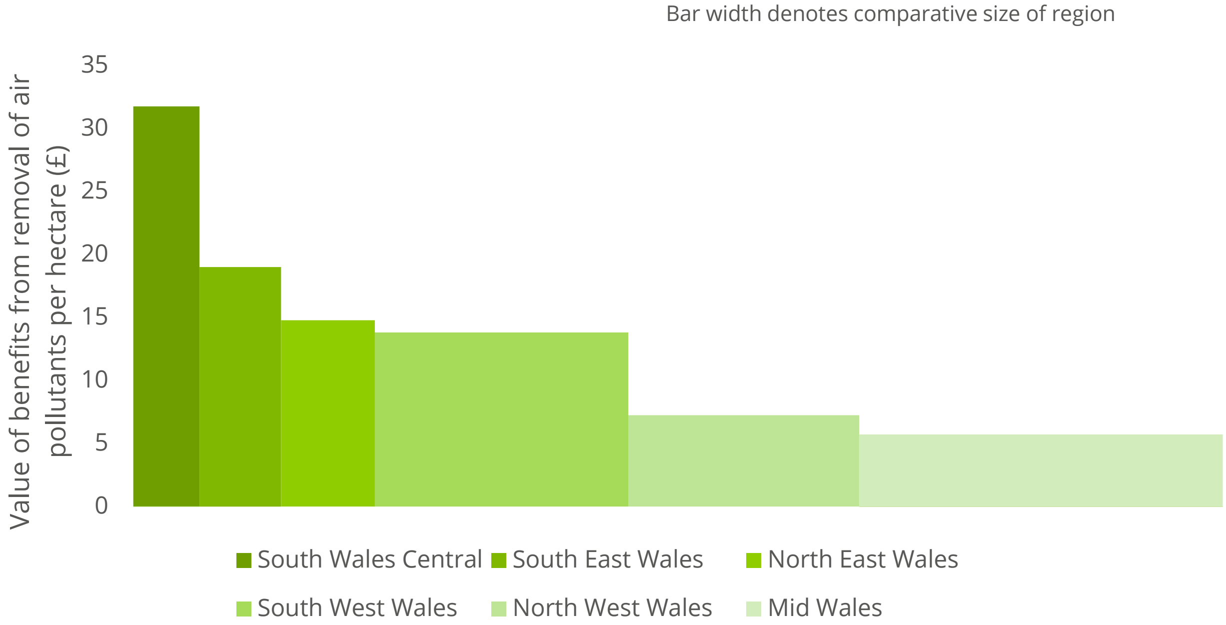

Figure 15: Present value of benefits from removal of air pollutants per hectare per year from SFS3 10 modelling scenario by Welsh region (£, 2020 prices, PV75, 1.5% discount rate reducing to 1.29% from year 31)
Source: IMP modelling

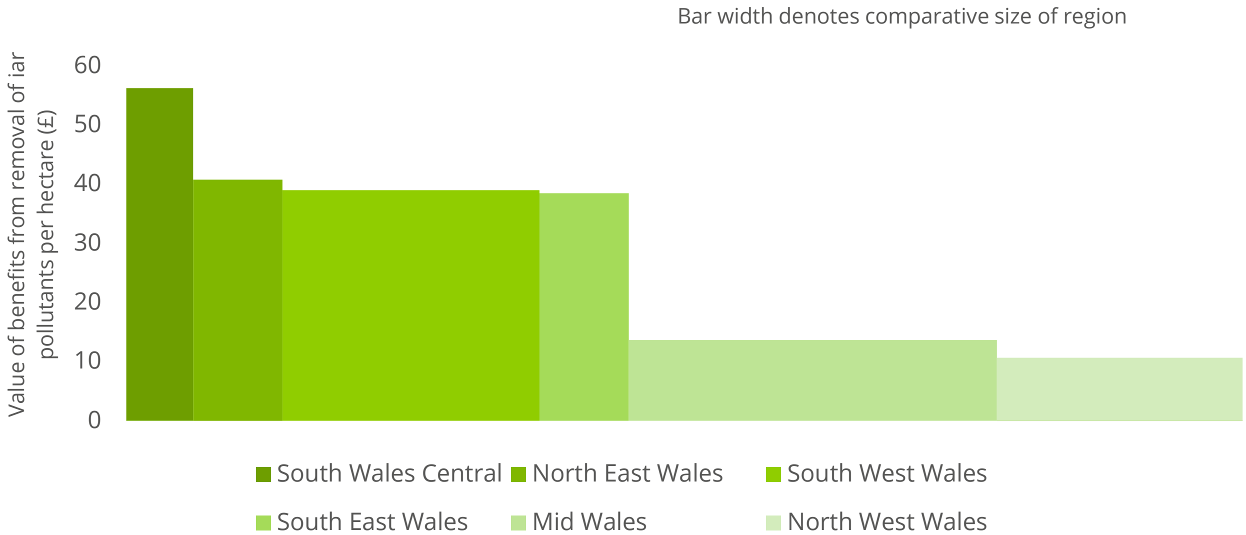

Figure 16: Present value of benefits from removal of air pollutants per hectare per year from SFS3 30 modelling scenario by Welsh region (£, 2020 prices, PV75, 1.5% discount rate reducing to 1.29% from year 31)
Source: IMP modelling

7.4 Recreation

Recreation benefits arise from visits to the natural environment that improve the welfare of visitors.

7.4.1 Access to green space

7.4.1.1 *How the benefit is assessed*

Recreational benefit is measured in terms of number of visits to accessible greenspaces, and the average welfare value associated with these visits. Welfare values are assessed based on a modelled demand function for recreation, which includes an assessment of the costs incurred to travel to a recreation site. The likelihood of visiting a site and the decision of whether to travel by car or foot is significantly influenced by the distance between the recreational site and the individual's home. For distances between 200m to 10km, the number of visits and the value derived decreases as the site gets further from an individual's home.

The ORVal[13] tool is used to estimate the number and welfare value of visits to the accessible open spaces within a given area. Estimates can be produced for various spatial breakdowns, including local authorities, national parks, and for the entirety of Wales. ORVal also breaks down the estimated number of visits and associated welfare value by socio-economic group.

ORVal modelling is based on MENE data (Natural England, 2018)[14] and The Welsh Outdoor Recreation Survey (WORS), which assessed participation in outdoor activities and attitudes towards biodiversity in Wales. It provides information on participation in a range of outdoor activities, from climbing to picnics, which take place in all areas from local parks to mountains and the sea, it does not take into account visits by children or overseas visitors to the UK, only domestic visits (Day and Smith, 2018).

Data from ORVal consider the location of the recreation asset, surrounding population, habitat type(s), and local alternatives. It does however make the assumption that accessible green space is in average condition for its type (e.g., all woodland is in the same condition). Areas where condition differs significantly from the average will have higher/lower values for both the number and welfare value of visits.

In the case of recreation, location plays a dual role; urban green spaces are more valuable due to limited alternatives and a significant number of potential users, but the value may be compromised by negative factors such as pollution or overuse. As mentioned above, ORVal struggles to factor such condition assessments into its values. Recreational value also has an economic impact, both directly and indirectly. Direct effects include increased property values adjacent to high-quality green spaces, while indirect effects result from attracting tourism and promoting outdoor leisure activities, generating revenue and creating jobs. However, these benefits are vulnerable to development or infrastructure that harms green spaces and are outside the scope of ORVal’s valuation model.

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[13] ORVal is a spatial model that shows the recreational sites, number of visits and the benefit to visitors using data from mapping tools, Monitor of Engagement in Natural Environment (MENE) survey and economic valuation literature. University of Exeter (2018) ORVal v2.0 - The Outdoor Recreation Valuation Tool. Available at: https://www.leep.exeter.ac.uk/orval/

[14] See here for details about MENE data: https://www.gov.uk/government/collections/monitor-of-engagement-with-the-natural-environment-survey-purpose-and-results

If people are active during their visits, recreation can also have measurable physical health benefits. Recreation visits can then be adjusted by a proportion deemed 'active'[15], and multiplied by a proxy for health costs avoided from the recreation activity. This will be considered in the next version of the report. However, the distribution of value of physical health across Wales will broadly follow the same patterns as recreation since the values are based on the number and location of active recreation visits. This would only differ to the extent that there are systematic differences between where 'active' recreation takes place (i.e., if more 'active' recreation visits take place in national parks).

7.4.1.2 *Spatial variation of recreation value in Wales*

In Wales, the value per visit varies between £3.06 and £4.31. Like air quality however, per hectare values of recreation from visits within a local authority are higher in areas with greater population and population density, (i.e., urban areas). Figure 17 shows Cardiff (annualised value of £400 per hectare of recreation visits) to generate the largest benefit and lowest to Powys (annualised value of recreation visits of £8 per hectare). Table A2.9 shows the full range of these values by local authority, demonstrating that present values (over 75 years) per hectare, in the case of densely populated areas, can be as high as £30,000 per hectare.

Aggregating the data to the regional level (see Figure 18) to mirror the IMP modelling process hides much of the specific local authority variation, but still demonstrates the strong inverse correlation between the size of the region and the annual present values of recreation per hectare.

[15] White et al. (2016) estimate that 51.5% of recreation visits[15] are 'active'. An 'active' visit is defined as meeting recommended daily physical activity guidelines either fully, or partially, during visits.

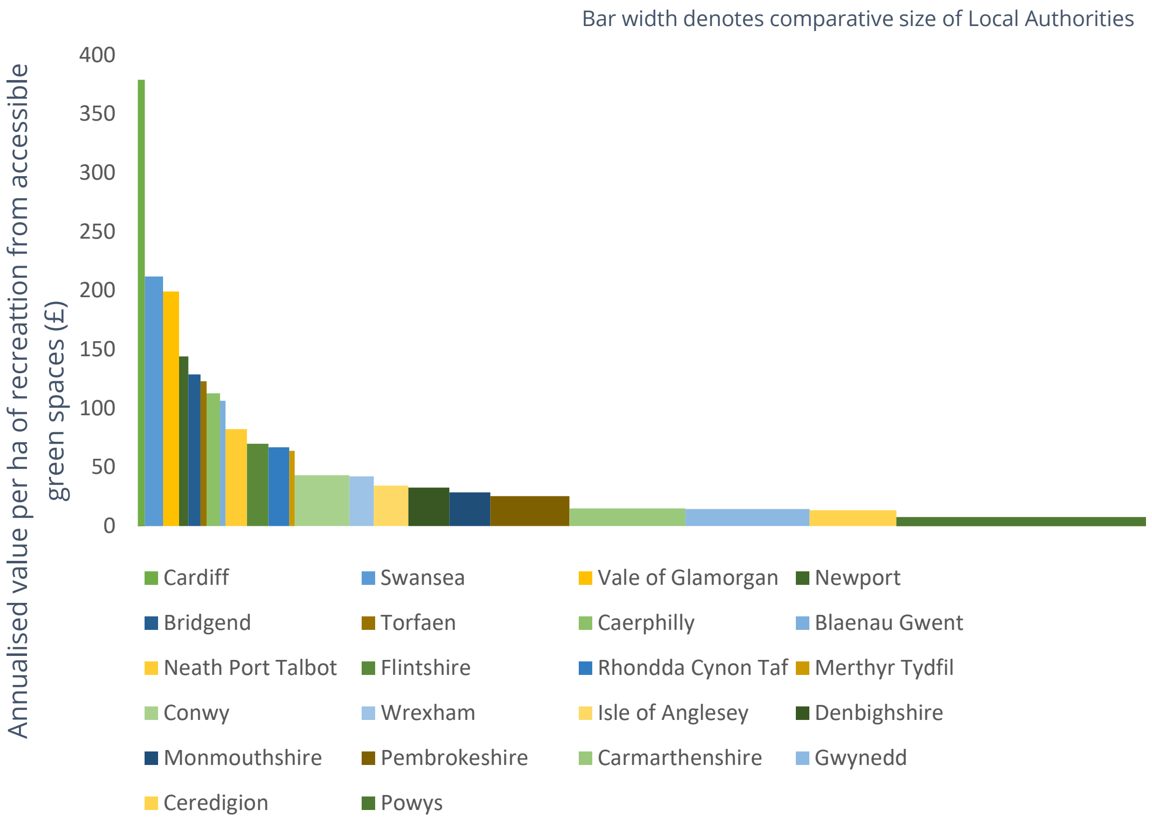

Figure 17: Average present value of recreation from accessible green spaces per hectare per year by Welsh local authority (£, 2022 prices, PV75, 3.5% discount rate reducing to 3.0% from year 31)
Source: eftec analysis from ORVal outputs (2023)

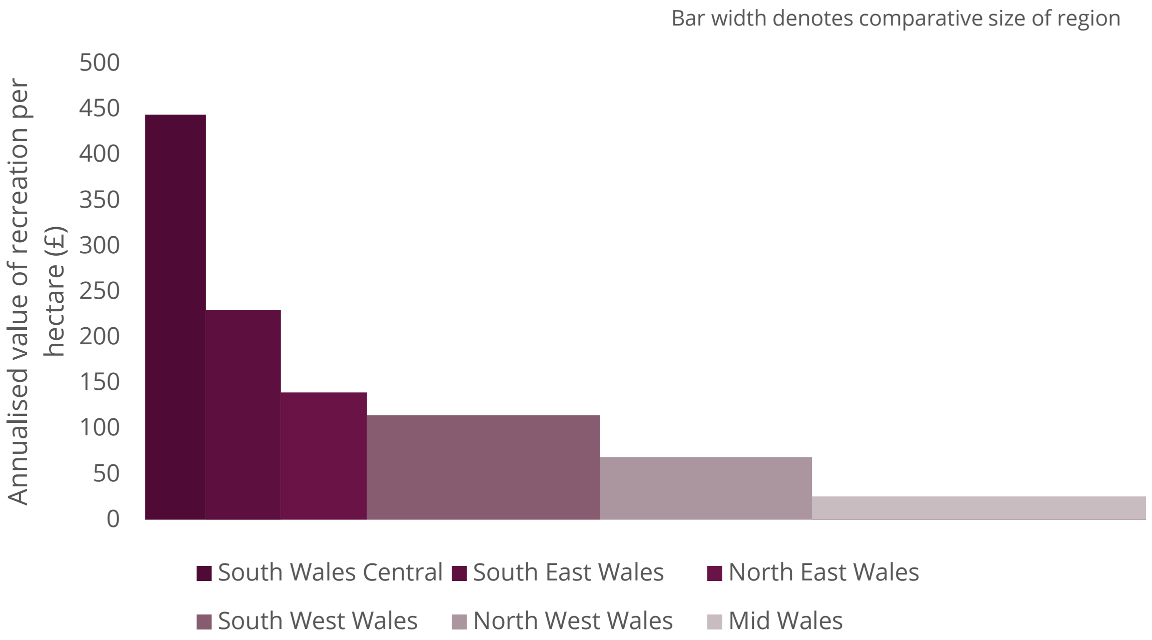

Figure 18: Average present value of recreation from accessible green spaces per hectare per year by Welsh region (£, 2022 prices, PV75, 3.5% discount rate reducing to 3.0% from year 31)
Source: eftec analysis from ORVal outputs (2023)

7.4.2 Physical health

Physical health benefits arise from recreational visits to the natural environment that are physically active. This activity improves the health outcomes of visitors, resulting in lower health treatment costs for society. It is therefore a distinct and additional benefit to the welfare associated with those visits measured under recreation.

7.4.2.1 *How the benefit is assessed*

The measurement of physical health benefits from nature is specifically based on those visits to greenspaces deemed as 'active'. This depends on the number and type of recreational visits. Therefore, the data on 'active' visits used to estimate the value of physical health benefits are a subset of those used in assessing recreation benefits in Wales.

Determining the number of 'active' visits requires extrapolation. This is typically assessed by assuming that a certain proportion of recreation visits are deemed active. White et al. (2016) estimate that 51.5% of recreational visits meet the definition of 'active'.

The value of these active visits is measured by the health benefits from active recreation (quantified in terms of Quality Adjusted Life Years – QALYs). It is valued based on the economic value of health improvement (avoided health costs) to derive the direct avoided medical treatment cost (£) per active visit. Beale et al. (2007) estimate the QALY per year per weekly visit[16], which is then adjusted by a cost-effectiveness threshold of QALY of £12,936 (in 2008 prices) per QALY (Claxton et al., 2015) (in 2008 prices)[17].

The estimated direct avoided cost in medical treatment per active visit is calculated by multiplying the QALY per week per active visit by the cost-effectiveness threshold. Based on the figures for 'active' visits used for recreation benefits, the country-level estimate of direct avoided medical cost treatment per active visit for Wales is approximately £3 to £4 in 2022 prices.

The Hall et al. (2021) study on the social benefits of woodland environments shows that there are wide health benefits from engaging with trees, woods and forests, although the mental health benefits of recreational activity (and the estimated monetary value) cannot neatly be separated from the physical health benefits due to the interconnections. The study cites research from Moseley et al. (2018) which concluded that the QALY ranged from £6 to £8,542 per person for individuals that undertook a single activity for at least 30 minutes, noting that values varied significantly due to the facilities provided, activities undertaken, frequency of visits and proximity of the population. According to the Hall et al. (2021) assessment, community woodland, national forest estate, urban trees and other greenspaces would each accrue varying degrees of mental and physical health benefits[18]. Moreover, they note that woodlands can tackle health inequalities under certain circumstances (e.g., socio-economic status, deprivation and geography/location) as population exposure to greenspaces and green environments is linked to health and health inequalities (Mitchell and Popham, 2008).

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[16] QALY per year is estimated at 0.010677

[17] The cost-effectiveness threshold is a proxy for health costs that represents the avoided health costs from an improvement of one unit of QALY.

[18] However, Hall et al. (2021) note that there is conflicting evidence on the mental health benefits of urban trees, where both benefits and disbenefits can be realised.

7.4.2.2 Spatial Variation of Physical Health Value in Wales

As with recreation values, physical health values are expressed in £ per hectare per year when analysing spatial variation in values at the local authority and regional levels in Wales.

Like air quality and recreation benefits, physical health is estimated to have higher £ values in areas with higher population and population density. Figure 19 shows that Cardiff is the local authority with the highest annualised value per hectare of physical health (£367 per hectare), and Powys with the lowest (£6 per hectare). Figure 20 shows that, at the regional level, South Wales Central (which includes Cardiff) exhibits a much higher annualised value of physical health (£41.60 per hectare) than other regions in Wales. This is nearly double that of South East Wales, the Welsh region with the second highest annualised value of physical health. Notably, as the total extent of the region increases, the value per hectare falls.

Hall et al. (2021) findings on forests and woodlands broadly confirm that social benefit values for physical health are spatially explicit and can vary by location as well as scale, although there is a lack of data on health values (particularly due to the difficulty in disaggregating mental health benefits from physical health) which would otherwise help to explain the spatial variation. While the evidence suggests that urban versus non-urban areas may vary in terms of spatial distribution of physical health values, more research is needed to understand this correlation and identify other factors that may influence this spatial variation in values of physical health benefits across local authorities and regions in Wales.

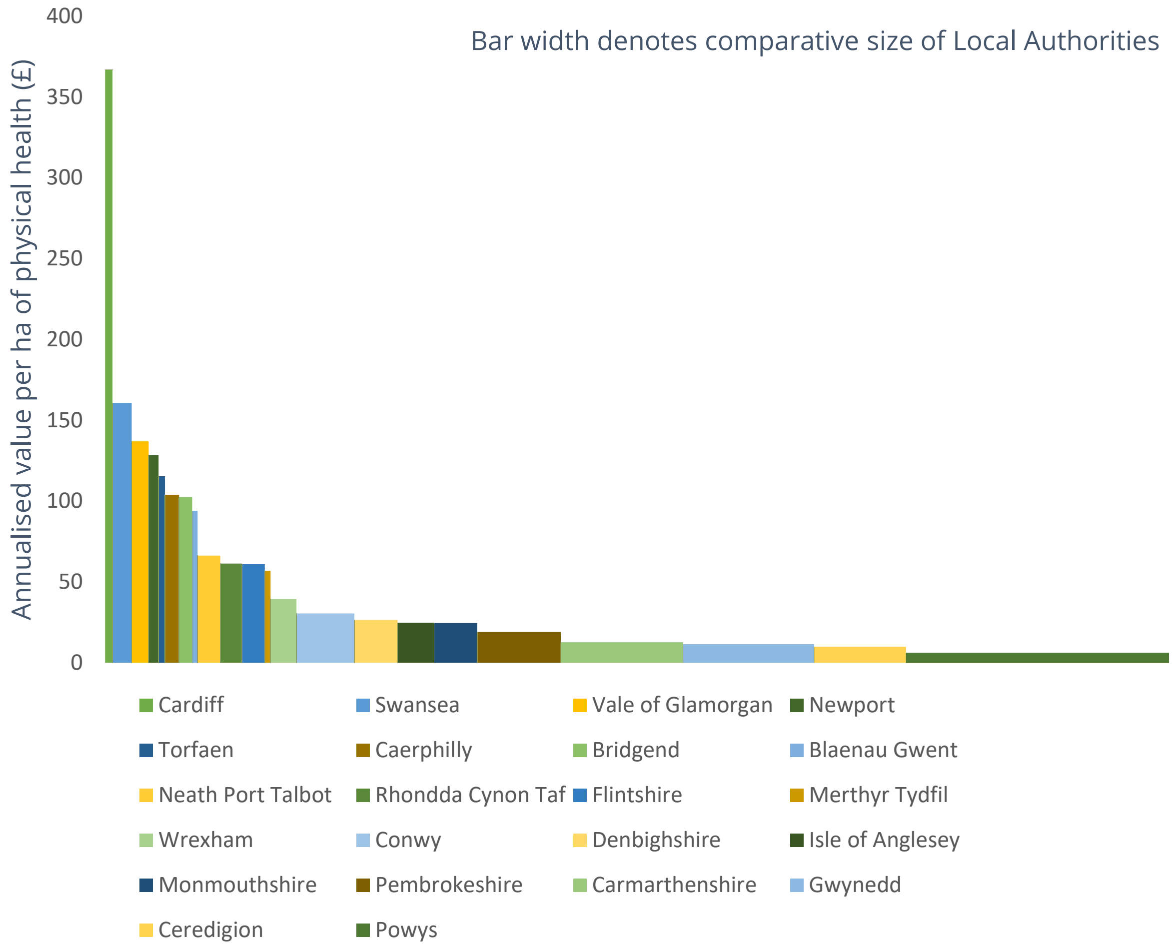

Figure 19: Average present value of physical health per hectare per year by Welsh local authority (£, 2022 prices, PV75, 1.5% discount rate reducing to 1.29% from year 31)
Source: eftec analysis from ORVal outputs (2023)

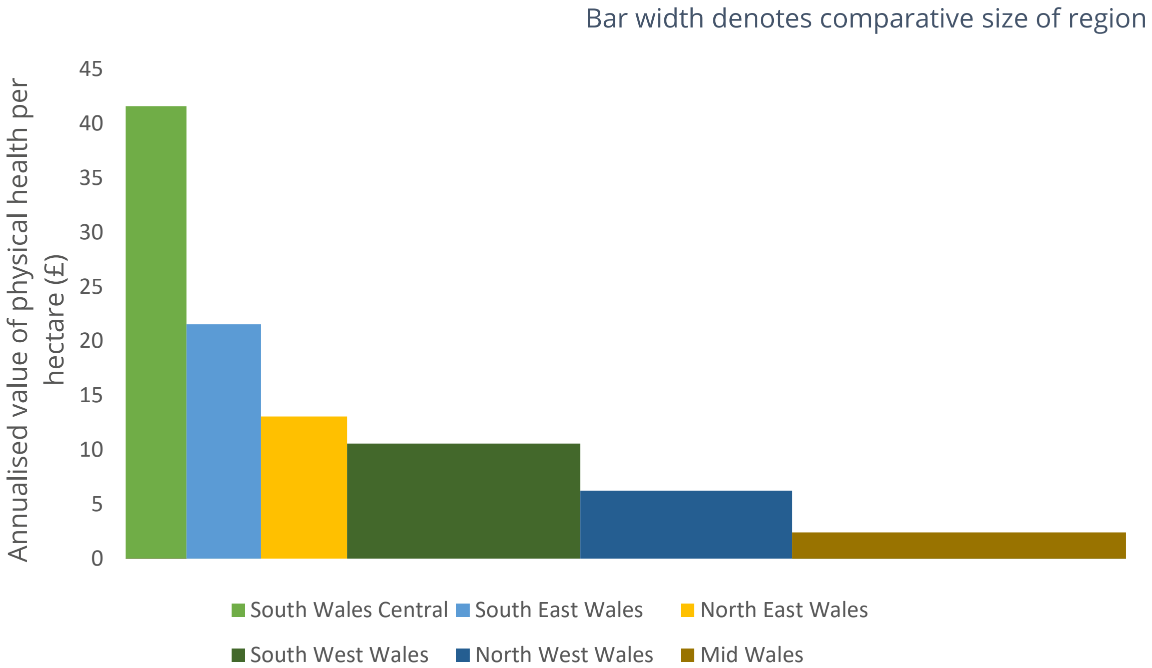

Figure 20: Average present value of physical health per hectare per year by Welsh region (£, 2022 prices, PV75, 1.5% discount rate reducing to 1.29% from year 31)
Source: eftec analysis from ORVal outputs (2023)

7.5 Flood risk management

Flood risk management is measured based on the capacity of natural ecosystems to mitigate the impacts of flooding and coastal erosion. Flooding imposes substantial social costs, including damage to property and infrastructure, harm to individuals, and further degradation of the environment.

Certain habitats inherently offer natural flood risk management services. Woodlands reduce the risk of flooding to downstream populations by reducing rainfall flows entering rivers. This reduction occurs due to canopy interception, higher soil infiltration, increased water storage capacity, impeded water flows, and reduced siltation. Woodland and other vegetation can also mitigate surface water flooding from heavy rainfall, which benefits urban communities by reducing the risk of sewage overflow.

Woodland and river management actions contribute to flood risk reduction in a variety of different ways (Keenleyside and Old, 2019). For example,

- **River and floodplain management** enhance the connection between the floodplain and the river, storing flood water and slowing waterflow. This also includes management of leaky barriers (in particular in areas where the floodplain is rough) and offline storage areas (to attenuate water flow).
- **Woodland management** can slow water flow depending on if the woodland is location on a) floodplain, b) catchment woodland (for smaller rainfall events), c) cross-slope woodland (reducing runoff from improved grassland), and d) riparian (slowing flows into floodplain).
- **Run-off management** which includes storing and slowing run off from open habitats before entering the river. This can include cover crops, buffer strips, and headwater drainage management.

Flooding around coastal margins are also mediated by habitats such as saltmarshes and floodplains. Both coastal and fluvial flood risk are predicted to rise due to climate change, as indicated in the UK Climate Change Risk Assessment (HM Government, 2022).

There is some evidence of small-scale flood risk benefits from habitat management and creation. Due to a lack or relevant monitoring data and modelling, and complexity of spatial configuration of catchments in relation to flood risk, there is little evidence to date which suggests that the benefits of natural flood risk management at small scales multiplies for larger scale catchments (Dadson et al., 2017; Hankin et al., 2017; Metcalfe et al., 2017).

Given the uncertainties related to understanding the downstream variation in local values for risk flooding, the values of this benefit are more suitable for national-scale policy appraisal rather than payment rates for farmers.

7.5.1.1 *How the benefit is assessed*

Quantifying the annual average damages for large scale flooding requires sophisticated modelling. Estimates of the quantity of water flow avoided and intercepted are required, alongside the probability, severity of flood events, and the number of properties protected.

The physical flow of the benefit is either measured in additional water storage capacity of woodland or vegetation intercepting water flow (measured in m^3) or number of properties protected. The ideal basis of valuation is the expected avoided damages arising from the flooding avoided. This should capture impact on people and assets at a local level. This evidence has not been systematically developed to allow comparisons of different levels of natural flood risk management benefits from farmland management actions in different locations.

The social value of these physical reductions in flood risk cannot currently be estimated in a robust manner without detailed modelling of the expected change in value of flood damage to downstream policy. There is no systematic analysis of this value that would allow comparison of the value of flood risk reductions across different areas of Wales. Therefore, there is no monetary value evidence that can be used to integrate flood risk reduction into payment rates. However, the understanding of the spatial variation in the benefit is based on the physical data available.

7.5.1.2 Spatial Variation of Natural Flood Risk Management Value in Wales

The physical flow of flood reduction benefits is likely to vary across Wales. This is for a variety of reasons (Fitch et al., 2022) including:

- **Location of properties** protected by woodland or intercepting vegetation within a catchment;
- **Tree type** (e.g., conifers intercept more rainfall than broadleaf species), **amount of cover, and age**;
- **Soil properties** (e.g., woodland soils are generally drier and therefore able to absorb more rainfall during significant flooding events); and
- Pre-afforestation drainage.

Each of these can make a different contribution to flood mitigation through their ability to reduce water flow speed, divert water into channels and pools, and impact in-stream processes.

Forest Research (2018, 2023) model the impact of existing woodland across the UK at regulating water flows and reducing flood risk. An advanced tool, the Joint UK Land Environment Simulator (JULES) model, was used to estimate floodwater storage of woodland (m^3) against a baseline grass cover. The model assesses woodland contribution to water flow reduction by considering:

- High potential water use (and storage) by trees;
- High infiltration rates of woodland soils;
- Hydraulic roughness; and
- Ability of trees to protect the soil from erosion and intercept sediment runoff into watercourses.

Of note are the following observations from the study:

- There is variation in spatial value across the UK. This is driven largely by a) different habitat types and categories, and b) drier climate in England meaning woodland water use is greater and soils are drier (and therefore have larger storage potential).

- Dryness of soil conditions beneath woodland has the largest influence on value across each UK country. Drier areas of Wales are therefore likely to benefit more from the flood reduction benefits provided by woodlands than wetter regions.

- Floodplain woodland has the most effective contribution to reducing waterflow but there is a comparative small extent of this habitat.

- Conifers are 2 to 3 times more effective than broadleaf species at intercepting rainfall (6mm to 8mm per storm day), but this impact is still small in overall terms. Similarly, conifers provide 5mm to 10mm additional storage compared with broadleaves.

Regarding natural flood risk management at various catchment scales, Keenleyside and Old (2019) note:

- Nearly all evidence is model-based at small scales;
- Incorporating this information would require a significant amount of site-specific modelling;
- Care should be taken when extrapolating small-scale empirical estimates to areas with different soils, vegetation and habitat; and
- There may be significant benefits for small catchments (<100km^2) when modelling small flood events (5 to 20-year return period), but there is little evidence to suggest that these will work at larger scales or for more extreme flooding events.

In total, the analysis shows that there is likely to be significant spatial variation in flood risk management value across Wales. This is determined by habitat differences, land usage, catchment characteristics, climatic conditions (both dry areas and regions with higher levels of rainfall), and by the downstream flood risk to people and property.

Notwithstanding the uncertainty of values and the multiple components of flood mitigation measures, one must remain cautious of misinterpreting a lack of evidence as evidence of insignificance. Each component plays a part in such a complex system, and a deeper understanding of these variations will lead to more effective, targeted natural flood risk management strategies.

7.6 Biodiversity

Understanding biodiversity in terms of its economic value presents complex challenges, as it encompasses diverse elements. According to the Convention on Biological Diversity (CBD), biodiversity is "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and ecosystems." This comprehensive definition suggests that biodiversity forms the bedrock of all ecosystems, lending immense value to the services they provide.

Various provisioning, regulating, and cultural ecosystem services are inherently linked to biodiversity. These include genetic material services, biological control services, and ecosystem and species appreciation. However, the exact measurement and valuation of biodiversity can often be a complex task, given that it encapsulates multiple components. Furthermore, the value attributed to biodiversity can significantly vary depending on habitat types, the types of benefits for biodiversity valued, and the methodology employed for valuation.

7.6.1.1 How the benefit is assessed

There are number of studies which offer key insights into methods required to place a monetary value on biodiversity. The differences in these studies can be described as a) the specific component or bundle of biodiversity valued, and b) how the value is elicited. These were summarised in previous work by Dickie and Neupauer (2019), with key information for the purposes of this report extracted in Table A1.7.

Table A1.7: Comparison of biodiversity valuation studies

Source: Adapted from Dickie and Neupauer (2019)

	Christie and Rayment (2012)	Christie et al. (2011)	eftec (2006)	Christie et al. (2006)	Boatman and Willis (2010)
The benefit being valued	Bundle of benefits (food/natural products, research and education, climate regulation, water regulation, sense of experience, charismatic/non charismatic species) related to the condition of priority habitats. Habitats include acid grassland; lowland calcareous grassland; neutral grassland; purple moor-grass and rush pastures; heathland; broadleaved, mixed and yew woodland; coniferous woodland; rivers and streams; canals; standing waters; bogs; fen, marsh and swamp; coastal and floodplain grazing marsh; inland rock; maritime cliffs; sand dunes and shingle; and intertidal mudflats and saltmarsh.	Bundle of benefits (wild food, non-food products, climate regulation, water regulation, sense of place (habitat benefits), increases in the population and range of threatened charismatic species (animals, amphibians, birds and butterflies), increases in the population and range of threatened non-charismatic species (trees, plants, insects, and bugs). Ecosystem services valued for the following UK Biodiversity Action Plan (BAP) habitats habitat types: arable margins; upland hay meadow; blanket bog; upland heath; hedgerows; coastal floodplain; limestone pavement; fens; low calc grassland; lowland raised bog; low dry acid grass; wet reed beds; lowland heath; native woodland; low hay meadow; arable fields; purple moor grass; improved grassland; and upland calc grass.	Upland farming attributes in each English region with Severely Disadvantaged Areas (SDA). Attributes include heather moorland and bog, rough grassland, broadleaf and mixed woodland, field boundaries, and culture heritage.	Bundle of benefits, divided into ecological and anthropocentric concepts. Attributes: (1) familiar species of wildlife (2) rare, unfamiliar species of wildlife (3) habitat quality and (4) ecosystem processes. The habitat was broadly defined as farmland in England. The study used a choice experiment to value biodiversity attributes.	Bundle of benefits (increased wildlife, enhanced landscape, carbon sequestration and lower carbon emissions) resulting from the Environmental Stewardship (ES) Scheme in England. Wildlife and landscape impacts are valued through a Stated Preference (SP) study. The change in carbon emissions attributable to ES is valued through estimating the reduction in carbon emissions due to land-use changes and using the DECC (2009) carbon price (which is based on the cost of mitigation to meet carbon reduction targets in the UK).
How the benefit was valued	Changes in ecosystem services were either a 25% increase or 50% decrease in food/other products, a 35% expansion or a 40% decline in research and education, an increase in storage or release of 100 kilo tonnes of CO_2 per year in carbon, 65,000 fewer people at a lower risk of flooding or 65,000 more people at a greater risk of flooding, a 35% increase or 40% reduction in the area of Sites of Special Scientific Interest (SSSI) habitat, and a 20% increase or a 55% decline in the population and range of threatened animals and insects. Changes in biodiversity and associated ecosystem services which results from 2 SSSI policy scenarios: i) meeting the target of 95% of SSSIs in 'favourable' or 'unfavourable recovering' condition	At the UK level, the full implementation of the BAP scenario involved an increase of 14% in the availability of wild food and non-food products, an increase of 708,000 tonnes of CO_2 sequestered each year, 67,000 fewer people at risk of flooding, 41.3% of habitats achieving favourable condition (compared to 37.3% in the baseline), all 273 threatened charismatic species stabilised (compared to 105 species stabilised and 168 in decline in the baseline), and all 876 non-charismatic species stabilised (compared to 337 species stabilised and 539 in decline in the baseline). The no further BAP funding scenario involved a decrease of 16% in the availability of wild food and non-food products, a decrease of 749,000 tonnes of CO_2 sequestered each year, 69,000 more people at risk of flooding, 27.6% of habitats achieving favourable condition, all 273 threatened charismatic species in decline, and all 876 non-charismatic species in decline. Changes in biodiversity ecosystem services resulting from i) a full implementation of the BAP and ii) no further BAP funding.	Improvements in quantity of heather moorland and bog (-2% to +2%), rough grassland (-10% to +10%) broadleaf and mixed woodland (+3% to 20%), field boundaries (for every 1km 50m to 200m is restored), and improvements in quality of culture heritage.	Changes in biodiversity attributes were (1) to protect rare familiar species from further decline or protect both rare and common familiar species from further decline or do nothing and allow continued decline, (2) to slow down the rate of decline of rare unfamiliar species or stop the decline and ensure the recovery of rare unfamiliar species or do nothing and allow continued decline, (3) restore habitats or re-create habitats or do nothing and allow habitat degradation to continue, and (4) to restore ecosystem services that have a direct impact on humans or restore all ecosystem services or do nothing and allow the	Implementation of ES compared to the absence of the scheme. ES is complex and involves incentivising farmers and land managers to take a variety of actions, however the most widely adopted actions in all landscapes are as follows: Entry Level Stewardship (ELS): Hedgerow management, ditch management, buffer strips and field corners, in-field trees, overwinter stubbles, permanent pasture with low inputs; Higher Level Stewardship (HLS): Grassland options, options for woodland creation, maintenance and restoration, hedgerows of high environmental value, lowland heathland.

	Christie and Rayment (2012)	Christie et al. (2011)	eftec (2006)	Christie et al. (2006)	Boatman and Willis (2010)
	and ii) all SSSI achieving 'favourable' condition.			decline of the functioning of ecosystem processes.	
Values	Estimates household consumer surplus values of six ecosystem services (wild food, research and education; climate regulation; water regulation; sense of experience; charismatic species; non charismatic species) delivered by conservation activities on SSSI habitats under the 'Maintain funding' scenario. Total value of all ecosystem services under the maintain scenario is £42.62 per household per year and for the increase funding is £34.74 per household per year. The willingness to pay for charismatic species, under the maintain funding scenario, is £19.21. This value can be disaggregated down to habitat level, where WTP for charismatic species on heathland is £7.66 and £1.67 for broadleaved, mixed and yew woodland. For natures gift (or wild foods), the overall WTP is £0.15. The WTP for ecosystem services is lower under the increase funding scenario. The attributes for the 'pooled' choice experiment model, except from non-charismatic species, are all statistically significant above 0.1.	Estimates consumer surplus values for the ecosystem services delivered by BAP habitats within 'own region' and in the rest of the UK. These results are disaggregated by country and ecosystem service. In Wales, within their own region, the WTP for non-charismatic species is £47 per household per year under an increased spend scenario and £74 under current spend scenario. For wild foods, the WTP is £15 for increased spend and £88 for current spend. There are no WTP for charismatic species in Wales as the results from the modelling were not statistically significant. For benefits delivered in the rest of the UK, only the water regulation benefit had statistically significant results. (Values from ENCA) UK WTP for enhancements to charismatic and non-charismatic species, and sense of place, associated with a significant improvement in habitat condition as a result of full implementation of UK Biodiversity Action Plans: £84 / hectare lowland heathland £75 /hectare coastal floodplain habitat £72 /hectare native woodland habitat £70 /hectare upland heath £55 /hectare hedgerows £53 /hectare blanket bog £34 /hectare purple moorland grass £8 /hectare improved grassland £4 /hectare arable field margins	eftec (2006) estimates WTP per household for habitats related to farming (heather moorland and bog, rough grassland and mixed and broadleaf woodland). Across the English regions, the WTP for a 1% improvement in heather moorland and bog habitats is £0.82 per household per year, for rough grassland is £0.51 and for mixed and broadleaf woodland is £0.81.	Christie (2006) estimates the mean annual consumer surplus per household for seven ecosystem services delivered under the two marginal change scenarios: increase current spend under BAP and maintain current spend under BAP. The total value of the increased spend scenario is £307 per household per year, and £403 per household per year for the current spend scenario. The WTP to protect rare familiar species from further decline is £36 in Cambridge and £91 in Northumberland. To protect both rare and common familiar species from further decline, those in Cambridge are WTP £93.49 and in Northumberland are WTP £97.71. To stop the decline and ensure the recovery of rare unfamiliar species, in Cambridge the WTP is £115 and £189.05 in Northumberland.	Boatman and Willis (2010) estimate the annual household WTP estimates for the Environmental Stewardship Scheme in England. The WTP for wildlife and landscape benefits is £22.41 (lower bound estimate).

The main conclusion from the table is that the unit values generated are difficult to compare and extrapolate to a policy context such as designing payment rates. This is because:

- The highlighted studies assess the value of the bundle of benefits provided by biodiversity, rather than a single attribute. Importantly, the bundles of attributes are often different when comparing studies. For example, Christie et al. (2011) and Christie and Rayment (2012) look across a range of ecosystem services associated with actions to enhance habitats and populations of charismatic species. In contrast, eftec (2006) and Christie et al. (2006) look at management actions on farmland habitats. The good that is being valued is different each time and it is not necessarily straightforward to adjust these values to match the SFS payment context.

- The benefit which is valued is often assessed as the difference between a baseline and policy scenario. The policy scenarios presented are different across the mentioned studies, and different from what may happen under the SFS action layers.

- There is likely spatial variation in the value of different attributes of biodiversity. This appears to be determined by the habitat in question. Table A1.7 shows how the value of different attributes may differ across attribute and habitat type (Christie and Rayment, 2012). In this study, the largest values are attributed to heathlands and the improvement in conservation status of charismatic species. Christie et al. (2011) suggest similar results, noting variation of £4 to £84 per hectare (2011 prices) by habitat type.

7.7 Water supply

Water supply involves abstracting water from surface and groundwater sources for not only drinking water and sanitation, but also industrial and agricultural purposes. It is a provisioning ecosystem service and is essential for industrial, agricultural and public water uses. Availability of water (i.e., quantity available for abstraction), climate variables and treatment costs are the primary factors affecting flow of benefits of water supply services.

7.7.1.1 How the benefit is assessed

The physical flow of water supply should capture the following: 1) current and projected demand and water abstraction levels, 2) weather forecasts and costs of ecologically excessive abstraction, 3) water movements by truck in periods of drought, and 4) restrictions on supply (ONS, 2020). Demand for water is expected to increase due to climate change and population growth (Environment Agency, 2018). Climate change effects are expected to lead to increased winter and reduced summer rainfall levels, resulting in winter floods and summer droughts.

In terms of monetary estimation, water supply is based on resource rents which are calculated for the SIC subdivision class 'Water collection, treatment and supply' (SIC code 36). A notable limitation of this is that this SIC code does not solely consider water supply, but also activities surrounding water treatment processes and "rents made in industrial applications."

Monetary estimates of water abstraction values for the whole of the UK is provided in ONS (2022) as shown in Table A1.8. Annual value is measured as the value of the benefit in a single year and asset value is the present value of the benefit over time. The data for annual value and asset value of water abstraction in ONS (2022) are only available at the UK-wide level.

Table A1.8: Physical flow, annual value and asset value of water abstraction in the United Kingdom, 2017 to 2021

	2017	2018	2019	2020	2021
Physical flow (mil m^3)	6,708	6,760	6,550	6,615	6,610
Annual value (£ mil, 2021 prices)	3,586	3,933	4,123	6,823	N/A
Asset value (£ mil, 2021 prices)	93,975	96,743	105,991	134,001	N/A

7.7.1.2 Spatial Variation of Water Supply Value in Wales

UK water abstraction breakdown by country is available from ONS (2022). Physical flow breakdown is included in Table A1.9 with an aggregate across the UK. Assuming that the unit value (£/m^3) is the same across the UK, this would amount to an annual value in Wales of £522 million and an asset value of approximate £10 to £20 billion.

Table A1.9: Water abstraction breakdown across the UK by country, mil m3, 2017 to 2021

	2017	2018	2019	2020	2021
Wales	506	514	490	506	512
England	5,332	5,346	5,163	5,206	5,160
Scotland	662	690	683	685	717
Northern Ireland	208	210	214	218	221
UK (total)	6,708	6,760	6,550	6,615	6,610

This table shows that quantity of water abstraction varies significantly across countries, with variation also evident over a five-year period within a given country. Physical land area (and water cover) can be a significant determinant of water available for abstraction between countries, although geographic and natural features affecting abundance of surface and groundwater are also factors in determining the supply of water available for abstraction and use. As noted above, exogenous factors such as climate change will affect water supply. This suggests that a unit value assumption (i.e., constant £/m^3 across the UK) is too simplistic to support land use policy design.

Moreover, water abstraction statistics for England available through Defra (2019) suggest that variation in water abstraction and use differ across the seven abstraction regional charge areas[19]. The data break down estimated for water abstraction from all sources except tidal by use and purpose: public water supply; spray irrigation; agriculture (excluding spray irrigation); electricity generation; other industry; fish farming, cress growing, amenity ponds; private water supply and other.

[19] The regional charge areas for England are North West, North East, Midlands, Anglian, Thames, Southern and South West.

It is expected that this spatial variation exists across different parts of Wales as well, arising from spatial variations in population (which would greatly determine the abstraction demand for public water supply) and water use intensity (for each of industry, agriculture and electricity generation).

The quantity of water demand should be considered alongside the quantity of water available for abstraction. The Environment Agency/Natural Resource Wales planning tables by Water Resource Zone (WRZ) is shown in Table A1.10 based on a dry year annual average (DYAA) or dry year critical period (CP) scenario. The table shows that total water available for use can vary widely across WRZs in Wales, from 1.00 to 51.73 Ml/d (millions of litres of water per day). This variation is also evident in household consumption (both measured and unmeasured) and non-household consumption across zones.

Table A1.10: Water supply and demand by Welsh Water Resource Zone, 2019 to 2020

Water Resource Zone and scenario	Supply (total water available for use, Ml/d), 2019 to 2020	Demand (unmeasured household consumption (baseline), Ml/d), 2019 to 2020	Proportion of demand (unmeasured household consumption)	Demand (measured household consumption (baseline), Ml/d), 2019 to 2020	Proportion of demand (measured household consumption)	Demand (non-household consumption, Ml/d), 2019 to 2020	Proportion of demand (non-household consumption)
Alwen Dee (DYAA)	51.73	15.29	39.15%	7.89	20.20%	15.87	40.64%
Bala (DYAA)	1.62	0.38	45.78%	0.16	19.28%	0.29	34.94%
Barmouth (DYAA)	1.55	0.38	33.33%	0.22	19.30%	0.54	47.37%
Blaenau Ffestiniog (DYAA)	1.77	0.71	65.14%	0.18	16.51%	0.20	18.35%
Brecon Portis (DYAA)	4.24	1.01	40.24%	0.54	21.51%	0.96	38.25%
Clwyd Coastal (DYAA)	22.13	6.14	39.08%	4.86	30.94%	4.71	29.98%
Dyffryn Conwy (DYAA)	31.90	7.65	42.45%	5.22	28.97%	5.15	28.58%
Elan Builth (CP)	7.64	2.48	47.24	1.40	26.67	1.37	26.10%
Elan Builth (DYAA)	5.64	1.39	39.60%	0.92	26.21%	1.20	34.19%
Hereford (DYAA)	43.85	10.36	36.87%	7.64	27.19%	10.10	35.94%
Lleyn Harlech (DYAA)	15.73	3.50	40.42%	1.47	16.97%	3.69	42.61%
Llyswen (DYAA)	3.69	0.64	40.25%	0.45	28.30%	0.50	31.45%
Mid & South Ceredigion (DYAA)	21.05	5.28	42.72%	2.61	21.12%	4.47	36.17%
Monmouth (DYAA)	4.11	1.29	49.24%	0.67	25.57%	0.66	25.19%
North Ceredigion (DYAA)	10.77	2.37	38.54%	1.20	19.51%	2.58	41.95%
North Eryri Ynys Mon (DYAA)	48.47	12.86	44.65%	5.22	18.13%	10.72	37.22%
Pembrokeshire (CP)	57.91	16.69	46.30%	7.69	21.33%	11.67	32.37%
Pembrokeshire (DYAA)	41.31	11.20	41.00%	5.51	20.17%	10.61	38.84%
Pilleth (DYAA)	2.28	0.76	52.05%	0.32	21.92%	0.38	26.03%
Ross on Wye (DYAA)	9.00	2.02	45.29%	1.21	27.13%	1.23	27.58%
SEWCUS (DYAA)	398.68	144.51	54.15%	56.99	21.35%	65.39	24.50%
South Meirionydd (DYAA)	2.50	0.63	43.15%	0.32	21.92%	0.51	34.93%

Tywi Gower (DYAA)	206.05	76.38	54.82%	29.76	21.36%	33.19	23.82%
Tywyn Aberdyfi (CP)	1.57	0.52	35.37%	0.46	31.29%	0.49	33.33%
Tywyn Aberdyfi (DYAA)	1.00	0.31	29.52%	0.30	28.57%	0.44	41.90%
Vowchurch (CP)	3.55	1.17	45.17%	0.61	23.55%	0.81	31.27%
Vowchurch (DYAA)	2.39	0.56	36.13%	0.33	21.29%	0.66	42.58%
Whitbourne (DYAA)	5.04	1.28	35.46%	0.80	22.16%	1.53	42.38%

In the public water supply context, “water supply” can be measured and valued as the treatment cost required to remove nitrates from drinking water (eftec, 2022). The eftec study, which concerned valuing consequences of enhanced nitrogen deposition in the UK, considered both the ecological and economic measurements of nitrogen deposition. In ecological terms, the physical flow is based on an assumption adapted from the methods used in Jones et al. (2014) whereby the proportion of atmospheric nitrogen deposition that ends up in water courses[20] is applied to all landcover in Great Britain excluding saltwater.

In deriving the estimated value of treating nitrogen pollutants in drinking water, the eftec (2022) study found that treatment costs depend on the source of the pollutants. In effect, the modelling requires understanding the expected breakdown of pollutant by source and applying different costing approaches. At a high level, these sources can be categorised as urban or agricultural. A more granular approach on pollutant sources is found in Hughes et al. (2008): direct deposition to water, urban runoff and leaching, sewage and industrial, agriculture, wood and natural areas, and particulate (Hughes et al., 2008).

Once the physical flow of nitrogen deposition is categorised according to the pollutant source, it is possible to estimate treatment cost by source. For urban nitrogen pollutant sources, the eftec (2022) report uses data from Ofwat (2006), estimated as £2.2 to £7.4/kgN (2006 prices) with an average of £4.8/kgN across all urban water treatment), whereas agricultural data are based on Chadwick et al. (2006), estimated as £0.70 to £1.3/kgN, with a central value of £1/kgN across different scenarios, as reported in ENCA). A final adjustment of the figures to represent the cost of treating nitrogen rather than nitrates showed treatment costs for urban and agricultural sources as £1.47/kgN and £0.26/kgN, respectively. These figures are suitable for application in different scenarios across the UK. However, the wide gap in treatment costs between urban and agricultural shows that spatial variation is a significant factor. Moreover, even within urban and agricultural scenarios, there are wide gaps in treatment costs depending on the specific type of pollutant source.

[20] The proportion of nitrogen deposition ending up in water courses is 22%, as taken from Billen et al. (2011).

8 ANNEX 2: DATA TABLES

8.1 Atmospheric carbon reduction

The total amount of CO_2-e sequestered by a given habitat in a given location in Wales is estimated by multiplying these per hectare rates with the total hectares of the respective habitat type. The amount of CO_2-e sequestered is then valued following the BEIS (2021) for the non-traded central price, £241 per tonne of CO_2-e in 2020. Future flows of carbon are valued using the BEIS (2021) carbon values series until 2050. Following BEIS (2021) advice, a real annual growth rate is then applied starting at the most recently published value for 2050 and into the future. Total emissions by peatland are estimated by multiplying the area of peatland that is near natural or degraded by the appropriate emission rate, and by the BEIS carbon values.

The non-traded prices of carbon are ranges for each year which demonstrate uncertainty around the social costs of (and therefore benefits of reducing) carbon emissions. These ranges are demonstrated in Table A2.1. For instance, for 2023 the value ranges from £126 to £378 per tonne of CO_2-e with a central value of £252. There is a steady upward trend in the value of carbon (from a central value of £241 in 2020 to £378 in 2050) to reflect the increasing value to society of reaching carbon reduction goals. This approach to valuation is recommended and cited by The Green Book (HM Treasury, 2022) and is used by the Office of National Statistics in the UK (and therefore Welsh) natural capital accounts (ONS, 2022).

Table A2.1: Carbon values per tonne of CO_2-e (£, 2020 prices)

Year	Low series	Central Series	High Series
2020	120	241	361
2021	122	245	367
2022	124	248	373
2023	126	252	378
2024	128	256	384
2025	130	260	390
2026	132	264	396
2027	134	268	402
2028	136	272	408
2029	138	276	414
2030	140	280	420
2031	142	285	427
2032	144	289	433
2033	147	293	440
2034	149	298	447
2035	151	302	453
2036	153	307	460
2037	156	312	467
2038	158	316	474
2039	161	321	482
2040	163	326	489
2041	165	331	496
2042	168	336	504
2043	170	341	511
2044	173	346	519
2045	176	351	527
2046	178	356	535
2047	181	362	543

Table A2.2: Carbon sequestration rates by habitat type and sub-type
Source: IUCN (2017); Natural England (2021)

Habitat type	Habitat description	Carbon sequestration (tCO_2-e ha^{-1} y^{-1})	Range
Woodland	Mixed native broadleaved woodland (100 year)	-7	-2 to -13
	Mixed native broadleaved woodland (30 year)	-15	-2.5 to -25.5
Hedgerow	Hedgerows	-2	-3.67 to -1.67
Orchards	Traditional orchard with low intensity management	-3	-5.89 to +1.65
	Intensive orchard	-6	-7.77 to -4.21
Heathlands	Lowland heathland & upland heathlands	Negligible	n/a
Semi-natural grasslands	Arable reversion to low input grassland	-2	n/a
	Undisturbed semi-natural grassland under long-term management	Negligible	n/a
Farmland	Arable land use	+0.3	n/a
	Improved grasslands	-0.4	-1.28 to +0.92
	Intensive grassland on deep peat soils	+25	n/a
	Arable on deep peat soils	+33	n/a
Peatland	Near natural	+1	
	Modified	+2.5	
	Drained	+4.5	
	Eroding	+24	

Table A2.3 to Table A2.5 provide associated data for the figures presented for atmospheric carbon reduction in Annex 1. Table A2.3 covers the average present value of carbon sequestration/emissions by habitat type and activity. Table A2.4 covers the present value of carbon sequestration from agriculture under SFS3 10 and SFS3 30. Table A2.5 also relates to the present value of carbon sequestration from agriculture under SFS3 10 and SFS3 30, but specifically arising from land use change and wetland emission reduction.

Table A2.3: Average present value of carbon sequestration/emissions per hectare per year by habitat type and activity (£, 2022 prices, PV75, 3.5% discount rate reducing to 3% from year 31)

Habitat type and activity	Value of carbon sequestration/(emissions) (£/tCO_2-e/ha/yr)
Mixed native broadleaved woodland (100 year)	979
Mixed native broadleaved woodland (30 year)	2,028
Intensive grassland on deep peat soils	3,479
Arable farming on deep peat soils	4,615

Table A2.4: Present value of carbon sequestration from agriculture per hectare per year arising under scenario management SFS3 10 and SF3 30 by Welsh region (£, 2020 prices, PV75, 3.5% discount rate reducing to 3.0% from year 31)

Welsh region	Present value of carbon sequestration from agriculture (£/ha/yr) under SFS3 10	Present value of carbon sequestration from agriculture (£/ha/yr) under SFS3 30
Mid Wales	2,990.7	8,076.9
North East Wales	2,025.0	6,378.5
North West Wales	2,681.8	4,483.6
South East Wales	2,715.9	6,822.9
South Wales Central	2,824.2	4,869.3
South West Wales	2,972.4	14,694.7

Table A2.5: Present value of carbon sequestration from agriculture per hectare per year arising under scenario management SF3 10 from land use change and wetland emission reduction by Welsh region (£, 2020 prices, PV75, 3.5% discount rate reducing to 3.0% from year 31)

Welsh region	Present value of carbon sequestration from agriculture (£/ha/yr) under SFS3 10 from land use change and emission reduction	Present value of carbon sequestration from agriculture (£/ha/yr) under SFS3 30 from land use change and emission reduction
Mid Wales	0.1	11.5
North East Wales	2.0	25.0
North West Wales	-5.0	-0.6
South East Wales	1.5	20.3
South Wales Central	-1.1	15.8
South West Wales	1.8	36.8

8.2 Water quality

8.2.1 Regulatory background

The Water Resources (Control of Agricultural Pollution) (Wales) Regulations 2021 is the key legislation that farmers and land managers in Wales must adhere to. The regulations came into effect on April 1, 2021, with the primary aim of reducing the release of pollutants from agricultural practices into the environment. New standards for silage making, silage effluent storage, and slurry storage systems were established and the regulations replaced previous regulations related to silage and slurry. They also consolidate nutrient management requirements into a single set of rules that simplify compliance.

The regulations apply to all farm businesses in Wales, regardless of their size. Owners or occupiers of agricultural land are responsible for following these rules. There are transition periods for farms not previously in a Nitrate Vulnerable Zone (NVZ). From April 1, 2021, requirements include silage storage, notifying Natural Resources Wales (NRW) about new silo or slurry storage system construction, controlling the spreading of nitrogen fertilisers, incorporating organic manures into soil or stubble, and adhering to closed periods for spreading manufactured nitrogen fertilisers. Additional requirements will be phased in from January 1, 2023, and October 31, 2023, with full compliance expected by August 1, 2024.

The regulations aim to address pollution incidents caused by inadequate storage, lack of capacity, and poor construction of slurry and silage effluent systems. By following these regulations, Welsh farms can demonstrate good practice and gain public confidence. For more information and assistance, farmers can refer to the Welsh Government's website or seek advice from Natural Resources Wales, the Welsh Government, or the Control of Agricultural Pollution Regulations (ADAS) Helpline. The requirements within these regulations will influence how data are collected, measured and reported at the farm scale, including monitoring of indicators to enable temporal and spatial valuation of benefits from reduction of pollutants.

Table A2.6: Central values (£/unit) employed in Farmscoper Evaluate tool to calculate environmental benefits

Pollutant	Units	Value (£ per unit)
Nitrate	kg-1 NO_3-N	£1.17
Phosphorus	kg-1 P	£39.76
Sediment	kg-1 SS	£0.47
Ammonia	kg-1 NH_3-N	£6.52
GHGs	kg-1 CO_2-e	£0.24

Table A2.7: Annual per component per hectare values (£, 2012 prices)

Welsh catchment	Length (km)	Bad to Poor (£)	Poor to Mod (£)	Mod to Good (£)
Conwy and Clwyd	438.23	2,390	2,718	3,129
Loughor to Taf	988.45	2,138	2,413	2,761
Middle Dee	265.74	3,032	3,498	4,069
North West Wales	1,133.34	1,889	2,111	2,397
Ogmore to Tawe	540.98	2,729	3,130	3,626
Severn Uplands	923.08	1,942	2,175	2,473
Shropshire Middle Severn	322.89	2,714	3,111	3,603
South East Valleys	500.19	2,919	3,361	3,904
South West Wales	1,074.00	1,869	2,087	2,368
Teme	546.11	2,407	2,739	3,154
Tidal Dee	39.69	3,247	3,758	4,382
Upper Dee	447.19	2,242	2,539	2,913
Usk	508.27	2,623	3,001	3,470
Wye	1,556.07	2,090	2,354	2,690

8.3 Air quality

8.3.1 Policy context

The Welsh Government implemented a Code of Good Agricultural Practice (CoGAP) in 2019 to reduce ammonia losses from agriculture in Wales. In 2021, they also launched an online tool to assist farmers in cutting ammonia emissions by providing practical advice based on the CoGAP guidance. In the same year, The Water Resources (Control of Agricultural Pollution) (Wales) Regulations were introduced, making it mandatory for all farms in Wales to adhere to requirements that aim to reduce ammonia emissions, including nutrient and manure management planning.

Currently, the Welsh Government is developing future support for agriculture after leaving the European Union, intending to replace the Common Agricultural Policy (CAP). The proposed SFS will replace the Basic Payment Scheme, and the level of payment will be linked to farmers' actions to achieve Sustainable Land Management (SLM) outcomes, including "clean air." The SFS will provide farmers with advice on lowering ammonia emissions, reward farming practices that reduce emissions, and support collaborative approaches for targeted actions to benefit ecosystems.

To meet climate change targets, the Welsh Government aims to plant significant areas of woodland by 2030 and 2050. The development of a National Forest for Wales is underway, which will include new woodland areas and the restoration of ancient woodlands. Tree planting near ammonia sources and sensitive sites will be supported through the SFS, as strategic planting has been shown to intercept or disrupt ammonia deposition. The Woodland Opportunity Map, an updated GIS tool, identifies areas where woodland creation can maximise ecosystem benefits, including intercepting ammonia deposition. Woodland proposals in areas with higher ammonia emissions receive higher scores for planting grants.

The following legislation will influence how data are collected, measured and reported at the farm scale, including monitoring of indicators to enable temporal and spatial valuation of benefits from reduce emissions to air:

The Clean Air Plan for Wales:[21] The Welsh Government aims to improve air quality and reduce air pollution through its Clean Air Plan. The plan The Clean Air Plan for Wales aims to improve air quality and minimise the negative effects of air pollution on human health, biodiversity, the natural environment, and the economy. The plan aligns with the national strategy, Prosperity for All, and focuses on reducing emissions and enhancing air quality to create healthier communities and better environments. The plan accounts for the impact of COVID-19 on air quality and incorporates actions to address it. It brings together various government departments and public sector organisations to meet or exceed UK and international guidelines and legislation.

The plan outlines a 10-year pathway to achieve cleaner air and is organised around four core themes: People, Environment, Prosperity, and Place. These themes prioritise protecting health, supporting the natural environment, collaborating with industries to reduce emissions, and creating sustainable places through better planning, infrastructure, and transport.

The plan emphasises evidence-based actions and includes regular monitoring, accountability, and stakeholder involvement, including consultation with farmers, growers, land managers, advisors and contractors. It proposes health-focused targets, a Clean Air Act for Wales, enhanced communication for behavioural change, improved air quality monitoring, and a legislative framework for air quality management. Additionally, it highlights efforts to control emissions in agriculture, enhance biodiversity and ecosystem resilience, work with industries to reduce emissions, promote ultra-low emissions vehicles, invest in active travel infrastructure, improve rail services, and facilitate the transition to electric vehicles through charging infrastructure planning and implementation.

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[21] https://www.gov.wales/sites/default/files/publications/2020-08/clean-air-plan-for-wales-healthy-air-healthy-wales.pdf

Net Zero Wales:[22] Wales has set ambitious targets to achieve net-zero greenhouse gas emissions by 2050. The Net Zero Wales Plan outlines the actions and strategies to reduce emissions across various sectors. The plan includes increasing renewable energy generation, improving energy efficiency in buildings, transitioning to electric vehicles, supporting sustainable agriculture and land management practices, promoting circular economy principles, and enhancing nature-based solutions. The Welsh Government also aims to engage with businesses, communities, and individuals to drive the transition to a low-carbon economy and achieve the net-zero emissions goal.

The Environment (Air Quality and Soundscapes) (Wales) Bill 2023:[23] The overarching aim of this bill is to improve air quality and reduce the impact of air pollution on human health, biodiversity, the natural environment, and the economy. The Bill will achieve this by facilitating improvements in air quality at various levels, including Wales-wide, local, regional, and throughout society. It also addresses the climate and nature emergencies and works towards reducing inequalities. In addition, the Bill includes changes to existing legislation to streamline and strengthen processes, making them more effective and accessible. Specifically, the Bill provides a framework for setting national air quality targets and amends existing legislation concerning the national air quality strategy, local air quality management, smoke control, clean air zones/low emission zones, and vehicle idling. Additionally, it places a duty on Welsh Ministers to promote awareness of air pollution and publish a national soundscapes strategy.

Table A2.8: Value of air quality benefits per hectare (£, 2022 prices)

Welsh local authority	Annualised value of air quality benefits per hectare (£) PV75 years	Value of air quality benefits per hectare (£) PV75 years
Cardiff	746	55,933
Newport	301	22,600
Torfaen	189	14,152
Blaenau Gwent	156	11,714
Swansea	130	9,724
Caerphilly	129	9,657
Vale of Glamorgan	121	9,059
Bridgend	121	9,060
Flintshire	97	7,296
Rhondda Cynon Taf	96	7,173
Wrexham	93	6,957
Merthyr Tydfil	89	6,669
Neath Port Talbot	31	2,297
Monmouthshire	28	2,114
Isle of Anglesey	20	1,520
Denbighshire	19	1,400
Conwy	15	1,126
Pembrokeshire	14	1,049
Carmarthenshire	13	981
Ceredigion	8	588
Gwynedd	7	514
Powys	6	444

[22] https://www.gov.wales/net-zero-wales
[23] https://senedd.wales/media/gbhlcgfn/pri-ld15738-em-e.pdf

Recreation

Table A2.9 describes the value of creation in different local authorities across Wales.

Table A2.9: Value of recreation benefits per hectare (£, 2022 prices)

Welsh local authority	Annualised value of air quality benefits per hectare (£) PV75 years	Value of recreation benefits per hectare (£) PV75 years
Cardiff	379	28,422
Newport	144	10,803
Torfaen	123	9,220
Blaenau Gwent	106	7,979
Swansea	212	15,894
Caerphilly	113	8,453
Vale of Glamorgan	199	14,937
Bridgend	129	9,656
Flintshire	70	5,241
Rhondda Cynon Taf	67	5,015
Wrexham	42	3,164
Merthyr Tydfil	64	4,790
Neath Port Talbot	82	6,173
Monmouthshire	29	2,143
Isle of Anglesey	34	2,574
Denbighshire	33	2,448
Conwy	43	3,237
Pembrokeshire	25	1,905
Carmarthenshire	15	1,121
Ceredigion	13	1,006
Gwynedd	14	1,082
Powys	8	573

Physical health

Table A2.10 describes the value of creation in different local authorities across Wales.

Table A2.10: Value of physical health benefits per hectare (£, 2022 prices)

Welsh local authority	Annualised value of air quality benefits per hectare (£) PV75 years	Value of recreation benefits per hectare (£) PV75 years
Cardiff	367	27,511
Swansea	161	12,049
Vale of Glamorgan	137	10,276
Torfaen	128	9,634
Newport	115	8,659
Caerphilly	104	7,792
Bridgend	103	7,697
Blaenau Gwent	94	7,052
Neath Port Talbot	66	4,977
Rhondda Cynon Taf	61	4,603
Flintshire	61	4,576
Merthyr Tydfil	57	4,263
Wrexham	39	2,962
Conwy	31	2,295
Denbighshire	27	1,994
Isle of Anglesey	25	1,859
Monmouthshire	25	1,844
Pembrokeshire	19	1,427
Carmarthenshire	13	956
Gwynedd	11	858
Ceredigion	10	739
Powys	6	465

9 ANNEX 3: COMPARISON OF BENEFIT VALUES ACROSS SPACE AND TIME

The findings and review of benefits presented in Section 4 and Annex 1 largely focus on the annualised present value per hectare (or kilometre) of natural capital benefits assessed over 75 years (PV75). The economic logic of selecting a 75-year horizon as the appropriate policy timescale of analysis in this context is that the benefits arising from the protection, enhancement or creation of natural capital and other related environmental management activities tend to manifest over a longer time horizon (e.g., spanning two or more generations) compared with other investment types.

It can take several decades to begin realising the benefits of actions and measures targeting climate change mitigation, reversal of biodiversity loss and species recovery. For this reason, The Green Book (HM Treasury, 2022) recommends 60-year time assessment periods which can increase up to 100 years. Hence, longer time horizons are preferred when assessing benefits flows from natural capital over multiple decades and determining the suitable rate or level of payments that farmers may receive in exchange. A longer timescale also conforms with the requirements of the Well-being of Future Generations Act 2015.

In terms of policy design, it is useful to consider the extent to which annualised values change as the period of assessment changes, and if so, the magnitude by which it varies with respect to the annualised average per hectare PV75 value.

This annex covers annualised present values per hectare (or kilometre) over five different timeframes: 5 years, 10 years, 25 years, 50 years, and 75 years. This analysis is performed for benefits where there is spatial variation across Welsh local authorities:

- Water quality;
- Air quality;
- Recreation; and
- Physical health.

The analysis demonstrates that there is significant variation in social value not only across different years of assessment, but also between Welsh local authorities for given benefit types.

9.1 Variation between catchments and local authorities

Tables A3.1 to A3.4 show annualised present values over 5-, 10-, 25-, 50-, and 75-year periods of assessment of natural capital benefits across sub-areas of Wales for each of water quality (per kilometre), air quality (per hectare), physical health (per hectare) and recreation (per hectare).

Table A3.1: Annualised present values for water quality for years 5, 10, 25, 50 and 75 by Welsh catchment (£ per km, 2022 prices)

Welsh catchment	PV5	PV10	PV25	PV50	PV75
Conwy and Clwyd	3,186	2,971	2,381	1,713	1,308
Loughor to Taf	2,828	2,637	2,114	1,521	1,161
Middle Dee	4,099	3,823	3,064	2,205	1,683
North West Wales	2,474	2,307	1,849	1,331	1,016
Ogmore to Tawe	3,669	3,421	2,742	1,973	1,506
Severn Uplands	2,548	2,377	1,905	1,371	1,046
Shropshire Middle Severn	3,646	3,400	2,725	1,961	1,497
South East Valleys	3,938	3,673	2,943	2,118	1,617
South West Wales	2,446	2,281	1,828	1,315	1,004
Teme	3,210	2,993	2,399	1,726	1,318
Tidal Dee	4,404	4,107	3,291	2,369	1,808
Upper Dee	2,975	2,775	2,224	1,600	1,222
Usk	3,518	3,280	2,629	1,892	1,444
Wye	2,759	2,573	2,062	1,484	1,133

Table A3.2: Annualised present values for air quality for years 5, 10, 25, 50 and 75 by Welsh local authority (£ per hectare, 2022 prices)

Welsh local authority	PV5	PV10	PV25	PV50	PV75
Cardiff	121	219	458	714	746
Newport	50	89	185	288	301
Torfaen	31	56	116	181	189
Blaenau Gwent	25	46	96	149	156
Swansea	21	38	80	124	130
Caerphilly	21	38	79	123	129
Vale of Glamorgan	20	36	74	116	121
Bridgend	19	35	74	116	121
Flintshire	16	29	60	93	97
Rhondda Cynon Taf	15	28	59	91	96
Wrexham	15	27	57	89	93
Merthyr Tydfil	14	26	55	85	89
Neath Port Talbot	5	9	19	29	31
Monmouthshire	5	8	17	27	28
Isle of Anglesey	3	6	12	19	20
Denbighshire	3	5	11	18	19
Conwy	2	4	9	14	15
Pembrokeshire	2	4	9	13	14
Carmarthenshire	2	4	8	13	13
Ceredigion	1	2	5	7	8
Gwynedd	1	2	4	7	7
Powys	1	2	4	6	6

Table A3.3: Annualised present values for recreation for years 5, 10, 25, 50 and 75 by Welsh local authority (£ per hectare, 2022 prices)

Welsh local authority	PV5	PV10	PV25	PV50	PV75
Cardiff	923	861	690	496	379
Newport	351	327	262	189	144
Torfaen	299	279	224	161	123
Blaenau Gwent	259	242	194	139	106
Swansea	516	481	386	278	212
Caerphilly	275	256	205	148	113
Vale of Glamorgan	485	452	363	261	199
Bridgend	314	292	234	169	129
Flintshire	170	159	127	92	70
Rhondda Cynon Taf	163	152	122	88	67
Wrexham	103	96	77	55	42
Merthyr Tydfil	156	145	116	84	64
Neath Port Talbot	200	187	150	108	82
Monmouthshire	70	65	52	37	29
Isle of Anglesey	84	78	62	45	34
Denbighshire	80	74	59	43	33
Conwy	105	98	79	57	43
Pembrokeshire	62	58	46	33	25
Carmarthenshire	36	34	27	20	15
Ceredigion	33	30	24	18	13
Gwynedd	35	33	26	19	14
Powys	19	17	14	10	8

Table A3.4: Annualised present values for physical health for years 5, 10, 25, 50 and 75 by Welsh local authority (£ per hectare, 2022 prices)

Welsh local authority	PV5	PV10	PV25	PV50	PV75
Cardiff	576	555	499	424	367
Newport	202	194	175	148	128
Torfaen	181	175	157	133	115
Blaenau Gwent	148	142	128	109	94
Swansea	252	243	218	186	161
Caerphilly	163	157	141	120	104
Vale of Glamorgan	215	207	186	158	137
Bridgend	161	155	140	119	103
Flintshire	96	92	83	70	61
Rhondda Cynon Taf	96	93	83	71	61
Wrexham	62	60	54	46	39
Merthyr Tydfil	89	86	77	66	57
Neath Port Talbot	104	100	90	77	66
Monmouthshire	39	37	33	28	25
Isle of Anglesey	39	37	34	29	25
Denbighshire	42	40	36	31	27
Conwy	48	46	42	35	31
Pembrokeshire	30	29	26	22	19
Carmarthenshire	20	19	17	15	13
Ceredigion	15	15	13	11	10
Gwynedd	18	17	16	13	11
Powys	10	9	8	7	6

Using PV75 figures as the baseline, the variation in annualised present values across space is described below:

- **Water quality**: the factor of variation between the Welsh catchment with the highest value (Tidal Dee) and lowest value (South West Wales) is approximately 1.8;
- **Air quality**: the factor of variation between the Welsh local authority with the highest value (Cardiff) and the lowest value (Powys) is approximately 124;
- **Recreation**: the factor of variation between the Welsh local authority with the highest value (Cardiff) and the lowest value (Powys) is approximately 47; and
- **Physical health**: the factor of variation between the Welsh local authority with the highest value (Cardiff) and the lowest value (Powys) is approximately 61.

It is notable from the tables above that values associated with Cardiff are significantly greater than the next largest Welsh local authority (Newport). Excluding Cardiff from the analysis still generates variation in value across local authorities of 20 to 50 (i.e., the annualised present value per hectare of natural capital benefits is 20 to 50 times larger in Newport than Powys).

Figure A3.1 and Figure A3.2 show how the annualised values change across time.[24] For each of the four benefits, there is a largely linear trend from PV5 to PV75. For water quality, the £/kilometre value of water quality decreases over time. This is also the case for physical health and recreation values (represented in £ per ha), with annualised recreation value falling at a slightly greater rate than that of physical health, ultimately converging near PV75. This arises due to a) the effect of economic discounting, and b) the assumption that annual health and recreation benefits remain constant over time. On the other hand, the annualised present value per hectare of air quality benefits increases from PV5 to PV75. From Figure 1, it is clear that using a 75-year period of assessment equalises the comparative annualised present values for air quality, recreation and physical. Using a 5-year period places greater relative importance on the recreation benefits (c.70% of the aggregate annualised present values per hectare).

[24] Water quality is measured as £ per kilometre, whereas air quality, recreation and physical health are measured as £ per hectare.

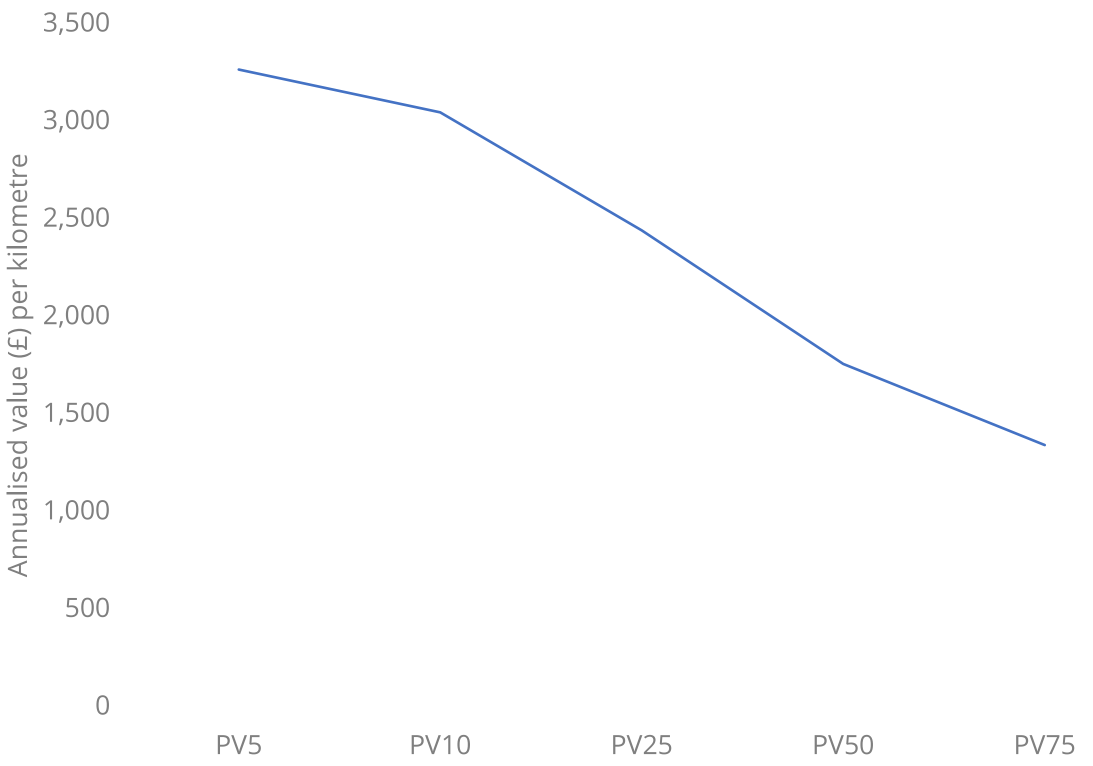

Figure A3.1: Change in annualised value of water quality benefits between years 5, 10, 25, 50 and 75 (£ per km, 2022 prices, 3.5% discount rate reducing to 3% from year 31)

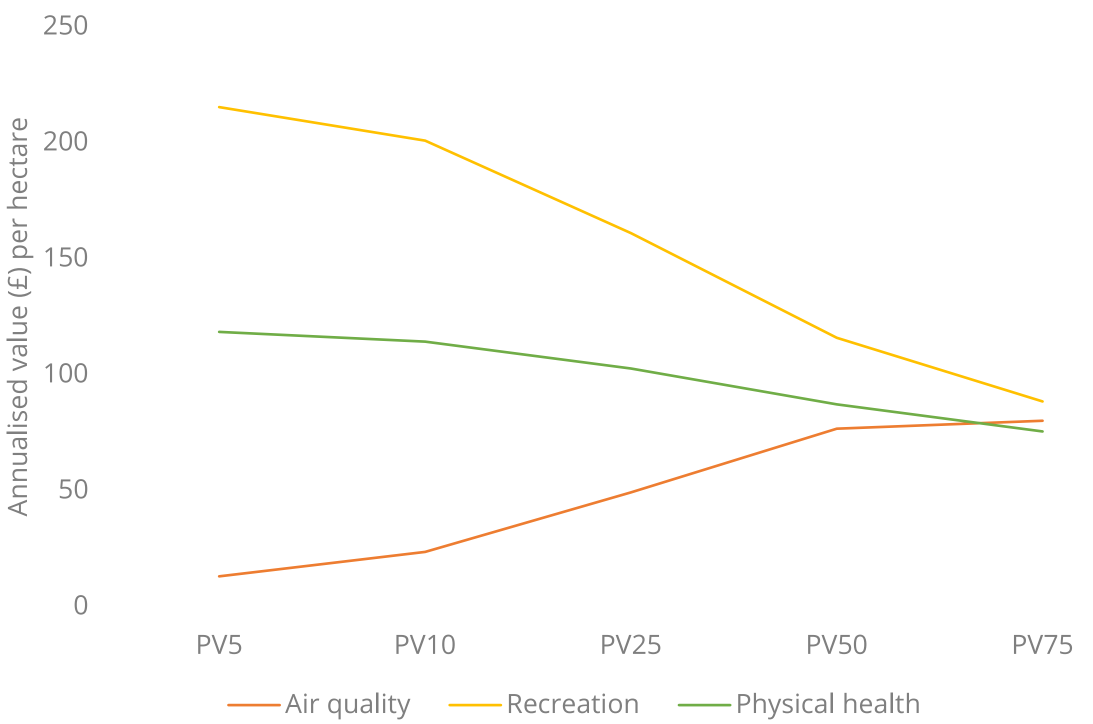

Figure A3.2: Change in annualised value of air quality, recreation and physical health benefits between years 5, 10, 25, 50 and 75 (£ per ha, 2022 prices; 3.5% discount rate reducing to 3% from year 31 for recreation, 1.5% discount rate reducing to 1.29% from year 31 for air quality and physical health)

10 Annex 4: SFS Bundle 3 – Nutrient and land management

Farms deliver a 10% improvement on manure spreading in comparison to the Water Resources Regulations. A stocking limit based on habitat land is also applied.

Farms undertake graze and rest, diversify swards, and ensure all cover crops are multispecies. Rotation rules ensure no more than two consecutive years are cereal, and a fertility building year must be introduced one year out of five.

Farms undertake soil testing (20% of land per year) and biosphere monitoring.

Intervention	Name	Description
ST1	Soil Testing	£10 per ha 20% of all land tested per year (including habitat and woodland) Include as time and capital cost Based on current Farming Connect rate – includes pH, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Mo, Zn, Se, Na, C & Cation Exchange Capacity, lime requirement
ST2	Soil Biosphere Monitoring	£15 per farm
F2	Scheme manure use baseline	10% improvement on individual ha limit of the Water Resources Regulations. Limit of 225 kg/N spreading per individual ha for all farms in scheme (250 kg/N in regulations). Average of 170 kg/N/ha across whole farm, including deposited by grazing animals (same as regs). Apply N max spreading limits (includes organic and artificial) to following categories of land: Improved grass – 225 kg/n/ha Habitat land – 0 Woodland – 0 Arable – 170 kg/n/ha (this is the average of the individual crop N Max Limits in the current NVZ) Note – where farm is over the limit, they are able to export manure off the farm.
S1	Stocking Limit/Natural Capacity	Stocking limit based on grazing capacity of different land/habitat types on the farm (linked to habitat management intervention)
S2	Graze and Rest	Animals moved every X days (X variable according to time of year and grass growth) within the current grazing period. (extending grazing period to be discussed for Phase 2) 50% of the improved grassland (temp and perm) of each farm in the scheme managed in this way. Includes feeding hay on pasture Dry matter content of the sward drives grazing time and rest period. AHDB recommend moving stock out when grass gets down to approx. 4 cm for sheep, and 5 cm for cattle.

		Move stock back in when grass is at least 8 cm for sheep and 10 cm for cattle Supplementary feeding may be needed for first and last rotation of season, but should not be from bought in feed. Approach to rotation grazing here: https://ahdb.org.uk/knowledge-library/how-to-develop-a-rotational-grazing-plan-for-cows-and-calves
GR1	Multi-species swards	Temp grass When re-seeding, 50% of total temp grass reseeded must be multispecies. Species list based on GS4 Countryside Stewardship. Perm Grass Any re-seeding must be broadcast (suggested graze hard first). When re-seeding, 100% must be multi-species Not for use on semi-natural perm grass
RO1	Fertility Building Year	1 year in 5 to be used as fertility building year. No use of artificial fertiliser in the building year only Graze where possible, else cut. If no black grass graze using mob/strip grazing with daily moves, no set stocking. Otherwise cut.
RO3	Multi-species cover/catch/break crops	All cover crops to be multi-species e.g., rye, vetch, phacelia, barley or mustard, can be sown, or other crops such as ryegrass or tillage radish
RO5	Two-year limit on mono cropping	No more than two consecutive years of cereals

11 Annex 5: Estimated income forgone of habitat creation and maintenance

The following data tables form part of the Welsh Government project C280/2019/2020 Phase 2 and 3 reports undertaken by ADAS, Pareto Consulting and SRUC on farm-level costs of proposed SFS Universal Actions measures. They demonstrate significant variation in income forgone between and within farm types, scaling per hectare costs (indicating an upward skew in distribution of income forgone. This is also the case for non-monetary metrics (e.g., number of livestock required to be reduced under the UA), with significantly higher reduction rates required for 80th percentile dairy farms in comparison with the median (see Table A5.10 to Table A5.12).

11.1 Semi-natural habitats

Table A5.1: Estimated 25th, 50th and 75th percentile income forgone (£) for field margins, by farm type

Source: Moxey et al. (2022)

Percentile	Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th	Farm-level	2,391	197	181	295	543	677	720	455
	Flat rate	32.21	2.74	2.74	4.76	10.55	9.32	8.52	7.74
50th (median)	Farm-level	5,122	456	396	697	1,110	1,446	2,273	1,225
	Flat rate	62.17	6.53	8.44	11.51	19.23	19.89	22.60	19.47
75th	Farm-level	9,454	949	793	1,436	2,305	2,480	5,553	3,414
	Flat rate	97.88	14.63	18.86	22.68	34.31	27.51	51.01	43.52

Table A5.2: Estimated income forgone (£/ha of new habitat) for farms required to create new habitat

Source: Thomson and Moxey (2023)

Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th percentile	249	0	0	0	0	102	346	0
40th percentile	540	0	0	0	0	102	549	0
Median	646	0	0	0	88	187	614	130
60th percentile	740	0	44	112	155	246	736	215
75th percentile	890	117	123	199	243	433	2,213	427
80th percentile	947	153	157	230	280	574	2,213	565
Mean	597	64	71	102	142	312	985	284

Table A5.3: Estimated habitat creation (ha/farm) on farms having to do so, by farm type
Source: Thomson and Moxey (2023)

Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th percentile	3.7	1.7	1.5	1.9	2.3	2.7	3.3	2.3
40th percentile	5.0	2.6	2.3	2.9	3.3	4.1	4.8	3.4
Median	6.0	3.0	3.0	3.6	3.9	4.9	5.7	4.3
60th percentile	7.0	3.5	3.7	4.4	4.7	6.0	7.1	5.1
75th percentile	9.5	4.7	5.6	5.7	6.4	8.2	9.3	6.9
80th percentile	10.5	5.4	6.1	6.4	7.2	9.4	10.5	7.9
Mean	7.5	3.6	4.0	4.3	4.9	6.6	7.5	5.4

Table A5.4: Estimated income forgone (£/ha of restricted land) for farms facing stocking restrictions
Source: Thomson and Moxey (2023)

Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th percentile	381	6	0	22	36	19	0	16
40th percentile	545	23	21	62	89	54	21	59
Median	632	41	46	91	122	96	73	93
60th percentile	735	65	71	120	158	144	131	130
75th percentile	902	106	122	179	230	233	420	227
80th percentile	980	119	137	201	254	264	674	287
Mean	509	83	81	94	447	228	513	307

Table A5.5: Combined habitat costs (£/ha of habitat land) for all farms
Source: Thomson and Moxey (2023)

Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th percentile	340	43	40	41	40	50	40	43
40th percentile	502	50	50	63	79	93	110	64
Median	593	57	58	85	114	119	169	91
60th percentile	680	69	71	111	151	152	230	127
75th percentile	841	97	107	165	225	239	526	222
80th percentile	918	110	125	186	257	269	594	279
Mean	600	81	87	115	153	181	398	203

11.2 Woodlands

Table A5.6: Estimated 25th, 50th and 75th percentile ongoing new woodland costs, by farm type (all sizes)
Source: Moxey et al. (2022)

Percentile	Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th	Farm-level	182	62	60	88	129	136	172	107
	Flat rate	2.76	2.40	2.34	3.45	6.41	10.20	4.30	11.77
50th (median)	Farm-level	328	252	211	229	242	284	329	257
	Flat rate	3.33	4.05	3.70	4.37	6.08	9.96	4.07	7.73
75th	Farm-level	550	535	467	399	385	521	639	470
	Flat rate	3.64	4.09	4.00	4.21	5.28	8.11	4.37	5.66

Table A5.7: Estimated woodland UA costs (£/ha of woodland) for all farms
Source: Thomson and Moxey (2023)

Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th percentile	50	50	50	50	50	50	50	50
40th percentile	365	51	50	55	85	78	50	58
Median	555	59	68	90	140	152	203	93
60th percentile	725	77	87	128	209	247	354	145
75th percentile	1,027	115	151	218	358	413	775	283
80th percentile	1,149	135	178	257	405	494	971	366
Mean	651	100	123	162	230	272	526	251

Table A5.8: Estimated woodland UA costs (£/ha of woodland) for farms required to create woodland
Source: Thomson and Moxey (2023)

Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th percentile	444	66	72	95	146	154	204	98
40th percentile	641	84	99	134	215	254	366	149
Median	763	99	123	170	282	344	463	196
60th percentile	916	116	154	211	344	406	667	267
75th percentile	1,189	162	219	296	444	557	1,127	442
80th percentile	1,310	183	255	338	473	610	1,448	536
Mean	858	132	170	223	327	390	759	356

Table A5.9: Estimated woodland creation (ha/farm) on farms having to do so, by farm type
Source: Thomson and Moxey (2023)

Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th percentile	2.3	2.2	1.5	1.8	1.6	2.1	3.1	1.9
40th percentile	3.5	3.3	2.6	2.7	2.5	3.1	4.0	3.0
Median	4.2	4.1	3.3	3.3	3.1	3.9	4.9	3.7
60th percentile	4.9	5.1	4.3	4.0	3.6	4.7	5.6	4.5
75th percentile	6.4	7.5	6.2	5.5	5.1	6.8	7.7	6.1
80th percentile	7.2	8.6	7.2	6.3	5.7	7.7	9.1	7.0
Mean	5.1	6.1	4.7	4.3	3.9	5.1	6.3	4.9

11.3 Additional information on impacts

Table A5.10: Estimated livestock displacement (GLU/farm) from habitat creation on farms having to do so, by farm type
Source: Thomson and Moxey (2023)

Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th percentile	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40th percentile	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Median	4.4	0.0	0.0	0.0	0.6	0.0	0.0	0.5
60th percentile	5.4	0.0	0.5	0.8	1.5	0.0	0.0	1.6
75th percentile	7.8	1.2	1.4	2.1	2.6	1.9	0.0	3.5
80th percentile	8.7	1.7	1.7	2.6	3.2	2.7	0.0	4.4
Mean	5.4	0.8	1.0	1.3	1.8	1.7	0.8	2.5

Table A5.11: Estimated livestock displacement (GLU/farm) from stocking restrictions on farms having to do so, by farm type
Source: Thomson and Moxey (2023)

Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th percentile	4.1	1.0	0.1	1.1	1.1	0.1	0.0	1.0
40th percentile	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Median	16.4	5.7	2.7	4.6	4.4	1.9	0.0	5.3
60th percentile	22.7	9.0	4.8	6.9	6.9	3.5	0.0	8.4
75th percentile	37.8	16.9	8.7	12.3	11.1	7.7	0.6	15.8
80th percentile	45.7	21.0	11.6	15.1	13.4	10.9	1.3	20.0
Mean	29.6	14.6	7.9	9.7	9.4	6.9	2.1	13.8

Table A5.12: Estimated livestock displacement (GLU/farm) from woodland creation on farms having to do so, by farm type
Source: Thomson and Moxey (2023)

Cost	Dairy	Sheep	Beef	Mixed grazing	Lowland grazing	Mixed	Arable	All
25th percentile	2.8	0.8	0.7	1.1	1.2	0.8	0.0	1.1
40th percentile	4.5	1.3	1.2	1.7	2.0	1.6	0.0	1.8
Median	5.6	1.7	1.6	2.2	2.6	2.1	0.2	2.4
60th percentile	6.6	2.2	2.1	2.7	3.2	2.7	0.8	3.1
75th percentile	9.0	3.2	3.1	3.8	4.3	4.2	1.8	4.6
80th percentile	10.1	3.6	3.5	4.3	5.1	4.9	2.8	5.5
Mean	6.9	2.5	2.3	2.9	3.4	3.4	2.1	3.6

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