THE ECONOMIC VALUE OF ECOSYSTEM SERVICES PROVIDED BY **CULM GRASSLANDS**

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CONTENTS

Cover photograph: Culm grassland at Bradworthy Common

1. SUMMARY

Culm grassland is an internationally important example of wet pasture that can provide multiple ecosystem services. It has experienced significant decline due to the intensification of agriculture with substantial areas lost since 1900.

Devon Wildlife Trust has long championed the value and importance of Culm grassland, and since 2008 the Trust's Working Wetlands project has worked with landowners to manage, restore and recreate Culm. This work has also formed a core element of South West Water's Upstream Thinking programme and recently it has been augmented by the delivery of the Northern Devon Nature Improvement Area (2012-2015). At the time of the University of Exeter review on which this work is based, a total of 3,984 ha of Culm grassland had been restored or recreated.

Previously there has been limited research into the type and value of a range of ecosystem services that this habitat can provide. However, between 2012-2015 a research project in partnership with the University of Exeter and the Environment Agency, sought to quantify these services in relation to water resource management and carbon storage, and in comparison with more intensively managed grasslands.

The data from this research has been used in this study as a basis for the first ever analysis of the financial values of Culm grassland. Led by Devon Wildlife Trust, and funded through The Wildlife Trusts' Strategic Development Fund, a project team from Montgomeryshire Wildlife Trust, the University of Exeter, the Environment Agency and South West Water worked alongside an independent consultant and expert in the field of economic evaluation of ecosystems to undertake this work.

The analysis considered several different values of Culm grassland, including the present contribution of existing Culm, the value delivered through Devon Wildlife Trust's Culm restoration work, and comparative values of Culm and intensively managed grassland. It also considered how the value of Culm grassland might vary depending on its proximity to a public water supply.

Undertaking this analysis highlighted the complexity in attributing financial values to ecosystems and posed a number of challenges. This particularly related to the choice of appropriate financial values, where often specific and discrete data of relevance to the Culm were not available, and the need to reduce comparative data to a common basis for the purpose of the analysis.

The key figures that have emerged from this study are as follows:

- it is estimated that the loss of water and carbon value from Culm grasslands, which have been converted to intensively managed grasslands since 1900 is £9.7 million at current prices;
- the work undertaken to date by Devon Wildlife Trust in the restoration of Culm grassland is estimated to have a potential benefit of £9.139 million by the time it has taken full effect; and
- the current Culm area has a marginal value of £14.723 million.

These figures indicate the significant financial values attributable to Culm grassland. In conjunction with the previous research to quantify the water resource and carbon storage capacities of Culm, they provide a strong case for the importance and value of continued investment in the maintenance, restoration and recreation of Culm grasslands.

Such restoration and recreation work provides an excellent return on investment. Over the next ten years, Devon Wildlife Trust aims to restore at least 5,000 ha more Culm, which will more than double its water and carbon value to in excess of £20.5 million. The cost of this investment in Culm restoration and recreation is in the region of £2 million, giving more than a ten-fold return on investment.

It has also highlighted the importance of an inter-disciplinary approach to analysis to enable environmental organisations such as the Wildlife Trusts to explore, understand and communicate the value of their landscape scale conservation work for both people and wildlife.

Through this analysis we have come to recognise that it is a complex task to determine and understand the relative costs of investing in and managing Culm grasslands as a soft engineering approach to improving water resource management, in comparison to investment in traditional hard engineering such as water treatment works. Therefore this study has focused on the value of the water and carbon assets of Culm grassland, rather than the value of the specific services delivered by this habitat. The latter requires further in depth analysis with South West Water and the Environment Agency to understand the methodologies and data used to calculate the costs of water treatment and flood mitigation in particular settings.

It is important that we use this study, its findings and identified challenges as a springboard for further investigation and partnership working. This report identifies a number of potential next steps to address these challenges.

2. INTRODUCTION

Each day the natural environment plays a multitude of vital roles in supporting our lives, with terms such as 'natural capital' and 'ecosystem services' used widely to describe this function. Whilst this is increasingly recognised and acknowledged, it is crucial that we continue to build the evidence base and showcase the key role of nature in providing solutions to pressing socio-economic issues.

Flooding at Dipper Mill in the Torridge catchment, North Devon, is a frequent occurrence

Devon Wildlife Trust is playing a leading role in building robust evidence in relation to the attributes of Culm, a wet grassland habitat found across north west Devon and north east Cornwall, in comparison to more intensively managed grassland. This research comes at a critical time, when tackling issues of flood risk management and the provision of safe, clean water supplies are high on political and socio-economic agendas.

In 2014 the Trust published the results of a cutting edge research programme, delivered in partnership with the University of Exeter and the Environment Agency, which explored and quantified the environmental ecosystem services delivered by Culm grassland. This research highlighted their significant attributes when compared to more intensively managed grasslands in relation to water storage and flood mitigation, water quality, and carbon storage.

This new report describes how we have taken this research data to build the first ever picture of the financial value of these ecosystem services. We recognise that this is critical if we are to secure future investment in our landscape scale conservation work in Devon, and more widely across the Wildlife Trusts movement. This type of work is challenging, and still in its early years, so studies like this are very important in building knowledge and exploring our understanding of good practice and different approaches that might be used in the future.

We hope that this report and the research upon which it is based can help government and utility companies in addressing the significant challenges of flood mitigation and the storage and provision of clean water supplies. In addition, this type of research is essential in advising and influencing debate about future land management, and how landowners and farmers can be supported to deliver a wide variety of services for their local and wider communities.

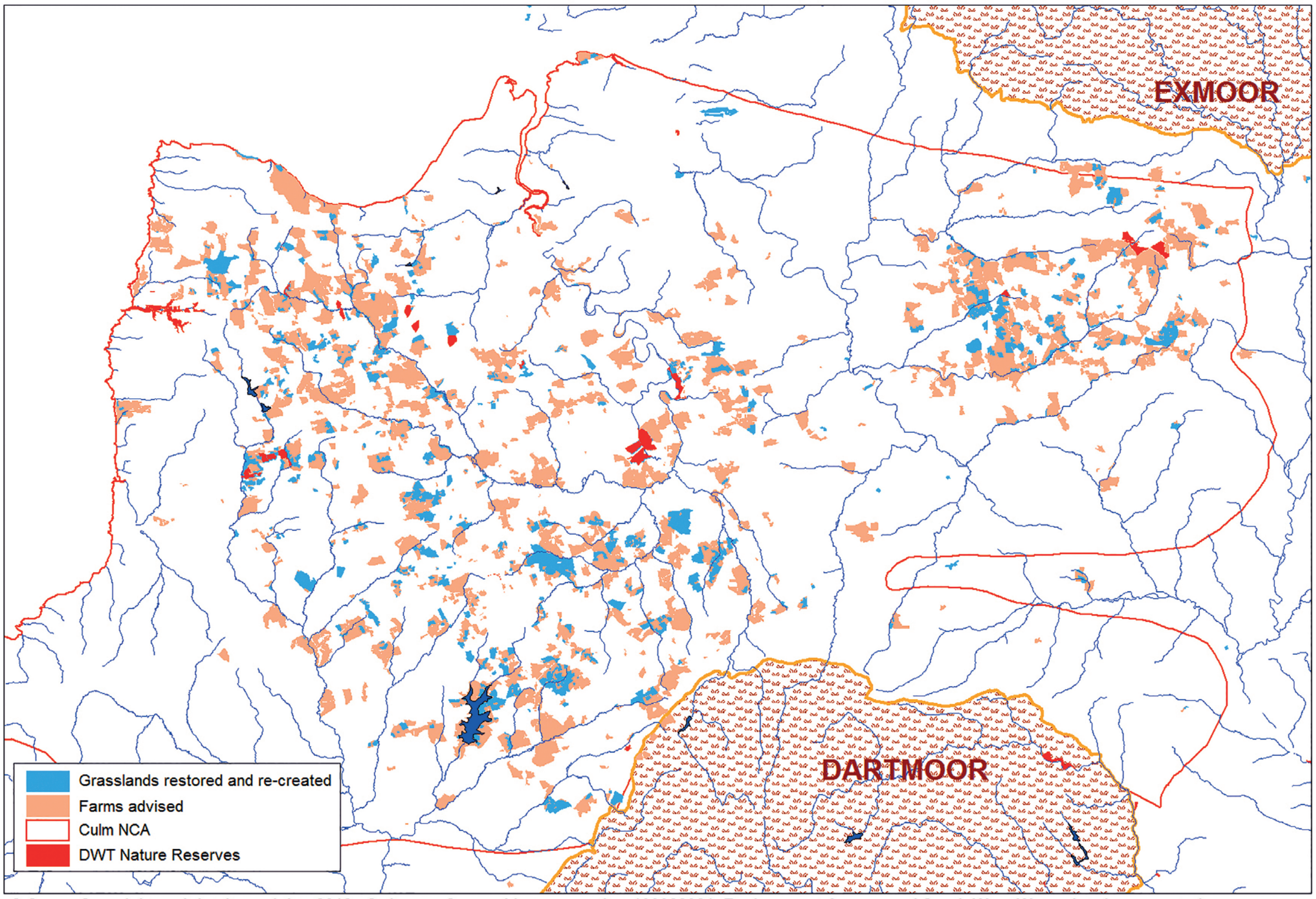
3. BACKGROUND – Culm Grassland

Culm grassland (purple moor grass and rush pasture) is a habitat of international conservation importance. These marshy grasslands, wet and tussocky in character, have traditionally been important for livestock grazing and are very rich in wildlife. The Culm National Character Area (NCA) covers 3500 km^2 in the south west UK, with Devon supporting over 80% of the remaining Culm grassland found in England. The extent of Culm grassland today indicates a loss of 87% against 1900 levels[1]. This loss is primarily due to agricultural improvement by drainage and the use of modern grass species in order to develop intensively managed grassland (IMG), capable of carrying more livestock or supporting forage production for longer periods. In some cases this has allowed milk production to take the place of beef rearing for example. In other areas the traditional grasslands have been undergrazed or not grazed at all, allowing scrub to encroach.

The recognition, conservation and enhancement of Culm grassland is a high priority for Devon Wildlife Trust. Since 2008 the Trust's Working Wetlands project has worked with landowners to manage, restore and recreate Culm grassland. More recently this work has been augmented by the delivery of the Northern Devon Nature Improvement Area (2012-2015). At the time of the University of Exeter review on which this work is based, a total of 3,984 ha of Culm grassland has been restored or recreated.

[1]*Hughes, M.R. and Tonkin, B., 1997. The Culm Natural Area. A Nature Conservation Profile. English Nature*

Culm restoration work can be carried out by spreading seed-rich green hay onto prepared pasture, or by



A map of the Culm National Character Area (NCA) showing the farms that DWT has worked with (in pink) and the sites restored (in blue).

harvesting, sifting and broadcasting seed from other wild-flower meadows.

4. PROJECT AIMS

This study was devised to undertake the following:

- To build on the existing research into the quantification of ecosystem services provided by Culm grassland and to attribute financial values to these services.
- To help build the economic case for the incorporation of the Wildlife Trusts' Living Landscapes approach into future flood mitigation and water quality enhancement schemes, and the delivery of other ecosystem services, notably carbon sequestration.
- To provide evidence to support the further development of the payment for ecosystem services (PES) approach.

In addition both South West Water and the Environment Agency wanted to better understand the potential financial benefits of investing in and supporting the restoration and recreation of Culm. South West Water recognised the need to continue to build the evidence base for their investment in their Upstream Thinking programme, which seeks to reduce the costs of water treatment downstream by working with landowners to improve water quality in the upstream reaches of river catchments. Similarly the Environment Agency was keen to better understand the value of Culm grassland in delivering Water Framework Directive and Flood and Coastal Risk Management objectives.

5. PROJECT APPROACH

This study was undertaken by a project team made up of Devon Wildlife Trust, Montgomeryshire Wildlife Trust, the University of Exeter, the Environment Agency, South West Water, and Charles Cowap (chartered surveyor and RICS registered valuer, Principal Lecturer in Land Management at Harper Adams University and Honorary Fellow at the University of Exeter). The basis for the study was the data produced from the Culm Grasslands Proof of Concept Study: Developing an understanding of the hydrology, water quality and soil resources of unimproved grasslands (Puttock and Brazier 2014).

6. ECOSYSTEM SERVICES FROM CULM GRASSLAND – the story so far

Culm grasslands provide a wide range of economic and societal benefits (ecosystem services) including:

- Capture and storage of carbon
- Reducing nitrogen and phosphate loads in water and soil
- Water storage
- Reduced suspended sediment loads in water
- Cultural and spiritual benefits arising from the landscape, biodiversity and habitat
- Education and research benefits
- Climate regulation
- Production of food and fibre

There has been very limited research to date that has sought to quantify and in some cases attribute financial values to these services. Examples of this are given below, which also highlight some of the challenges in undertaking this work.

6.1 Key terms in Environmental Valuation

As this study sought to convert absolute sums of water and carbon to capital values, it was necessary to consider some definitions and approaches to valuation. There are a number of specialised terms used in environmental valuation, which are explained below before a consideration of valuation studies undertaken to date.

Present Value, or Net Present Value (PV or NPV)

The concept of present value is based on the idea that money invested can earn interest. If we need £100 in one year we could invest a smaller amount today that would earn interest in order to grow to £100 when it is needed in one year. A consequence of this is that £100 available today is worth more than £100 received in one year's time, because today's £100 could be invested to earn interest and become a larger sum in future. To take a simple illustration: is one pound today worth the same amount as a pound to be received in one year's time? The concept of PV says not because the pound today can be invested to earn interest, so if the interest rate is 10% the pound will have grown to be £1.10. So it is better to accept the pound today than wait for one year. But if the pound is not receivable for a few years anyway, its value today will be lower. This reduction in value relates to the interest rate to be expected. Sticking with 10% a pound receivable in one year would be worth about £0.91 today because this sum can be invested at 10% to earn £0.09 in the year.

This is the basic idea behind discounting. Commercial calculations of NPV will use interest rates related to an investor's perception of risk and desired return. Environmental valuation often uses a standard discount rate used by the government for economic planning, which has been 3.5% for some time. NPV allows us to bring a series of future receipts and expenditure back to a single value today. Table 1 shows a simple example using a rate of 10% over a period of 5 years, applied to an annual value of £100.

Years	Annual sum (£)	Discount factor	Present value (£)
1	100	0.909	90.91
2	100	0.826	82.64
3	100	0.751	75.13
4	100	0.683	68.30
5	100	0.621	62.09
Total Present Value			**379.08**

Table 1: Simple illustration of discounted future values

Discount Rate

Discount rate is the percentage rate of interest used to discount future receipts or expenditure to a value today. For example £1.21 discounted at 10% for two years would equal £1.00 today - £1.00 for one year at 10% grows to £1.10, and for the second year the accumulated sum grows at another 10% to become £1.21 after two years. Therefore the right today to receive a payment £1.21 in two years discounted at 10% (the discount rate) is £1.00. The formula for this is $1/(1+i)^n$ where i is the interest rate (expressed as a decimal) and n is the number of years to be discounted. In practice the discounting factors are either drawn from standard spreadsheet functions, or more traditionally from discounting tables. Various tables for this purpose were first published as early as the 19th century. As identified above, environmental valuation often uses the figure of 3.5% as a discount rate.

Willingness to Pay (WTP)

Environmental Valuers use a number of approaches to arrive at valuations, in the absence of direct transaction evidence from a functioning market. One of these involves judging people's willingness to pay for an environmental asset, or to prevent environmental degradation. Once enough data have been gathered a price can thus be placed on an environmental asset. One of the drawbacks with WTP is that individuals' stated preferences can be quite different from their revealed preferences. For example we may all say that we are willing to pay an extra two pence in the pound in tax for the health service, one penny for education and so on (a stated preference) but when it comes to exercising a choice at the ballot box many of those who stated these preferences will in fact vote for lower taxes (their revealed preference through their voting behaviour).

6.2 Valuing ecosystem services: case studies from Lowland England Reconnecting the Culm project: Devon (Natural England 2012)

A study by Eftec for Natural England (2012)[2] sought to put a value on cultural, spiritual, landscape and aesthetic elements of the Culm grasslands. It excluded the value of carbon sequestration in soils and water quality and quantity benefits. However carbon sequestration via changes in livestock management were included in the study, but based on a considerable number of assumptions about changes in stocking policy. At 2010 prices the values for the selected ecosystem service changes were estimated to be:

- Cultural, spiritual, landscape, aesthetic and biodiversity/habitat: approximately £33 million a year, based on willingness to pay (WTP);
- Education and research: reaches £27,000 a year, and reflects the estimated cost for a school class visit (including cots of teachers, costs associated with children in education and payments to farmers for educational visits under Higher Level Stewardship schemes).
- Climate regulation: approximately £125,000 a year based on changes in emissions per hectare arising from reduced stocking levels on more traditionally managed grasslands (but this figure does not include values of carbon sequestration, which were not part of this study).
- Food and fibre, based on HLS payments as a measure of opportunity cost for forgoing more intensive agricultural production. Estimated at a cost of £1,237,582 a year on an ongoing basis from 2014.

This short summary illustrates the enormous challenge of valuing environmental services with the individual elements varying from £27,000 a year to £33 million a year. These difficulties are compounded when the results are converted to a capital value. The Net Present Value (NPV) over 10 years is put at £282 million, over 50 years at £266 million and over 100 years at £260 million. The reduction in NPVs over the longer periods raises obvious questions. The principal reason for this reduction is that the authors of this report decided to discount the cultural, spiritual, landscape, aesthetic and biodiversity/habitat benefits over the first 10 years in all the present value estimates. All the other benefits and costs however (including the administration and running costs of the Culm project) have been discounted over the full appraisal periods. The discount rates for this purpose were the standard HM Treasury rates (3.5% declining to 2.5% for later periods).

Other work has placed an ecosystem services value on wetlands ranging from £2,792/ha/year to £17,279/ha/yr (Morris and Camino 2011, Brander et al 2006, Everard 2009)[3] for all services aggregated.

[2] Natural England (2012) NECR101 Valuing ecosystem services: Case Studies from Lowland England Annex 6: Reconnecting the Culm project: Devon, Natural England, August 2012

[3] Morris J and Camino M 2011 UK National Ecosystem Assessment Working Paper, Economic assessment of freshwater, wetland and floodplain ecosystem;

Brander LM, Florax JGM and Vermaat JE (2006) The empirics of wetland valuation: a comprehensive summary and a meta-analysis of the literature Environmental and Resource Economics 33:223-250

Everard M (2009) Ecosystem Services Case Studies Reading, Environment Agency available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/291631/scho0409bpvm-e-e.pdf

6.3 Culm Grasslands Proof of Concept Study (Puttock and Brazier 2014)

Puttock and Brazier (2014) document carbon, nitrogen and phosphorus concentrations in water sourced from Culm grasslands in comparison to intensively managed grassland (IMG), and water storage characteristics of both Culm grasslands and IMG. On the basis of field monitoring from 2012 to 2014 they estimate that the NCA has the capacity to store 9,430Ml of water (plus or minus 2,807 Ml) and 715,402 tonnes of carbon (plus or minus 167,327 tonnes). These estimates are based on detailed work over an extensive period on three sites. Clearly their extrapolation over the full extent of the NCA introduces significant scope for variation, but they do provide the best starting point in terms of physical data for the consideration of reduced flood risk, enhanced water supply, lowered diffuse water pollution and carbon storage. It is helpful to introduce these data at a common spatial level and in the context of four different study scales. Table 2 shows the original data from Puttock and Brazier (2014), converted into the common basis of m3/ha in the final column for the purpose of this study.

Service or feature	Original base	Quantity	m^3/ha
Culm water storage	l/m2	277	2,770
IMG water storage		61	610
Difference		216	2,160
Culm topsoil depth	cm	47	4,700
IMG topsoil depth		27	2,700
Difference		20	2,000
Culm carbon storage	g/cm2	1.8	180
IMG carbon storage		1.5	150
Difference		0.3	30
Total Present Value			**379.08**

Table 2: Physical storage of water and carbon, m^3/ha

Puttock and Brazier report a range of values for water and carbon storage, and the figures quoted above are the reasonable mid-range figures used by Devon Wildlife Trust in summarising their work (Devon Wildlife Trust, not dated)[4]. In addition to these conclusions, Puttock and Brazier also estimated that the storm runoff would on average be 11 times greater from IMG than Culm, drawing comparisons with a range of other IMG landscapes studied in the region over the last ten years. Even when saturated, Culm has a reasonable ability to store water temporarily due to its uneven, tussocky surface which has the ability to form pools of standing water for more gradual release later. The relative importance of this in terms of its potential to reduce sediment runoff can be seen in relation to the Roadford Reservoir where it is estimated that sediment runoff of 230 tonnes a year could be reduced by 30 tonnes a year if the area of Culm were to be restored to 1947 levels (455 ha).

[4] *Devon Wildlife Trust, not dated:* ***The ecosystem services provided by Culm Grasslands*** *Devon, Devon Wildlife Trust*

University of Exeter installed an instrumented flume at Stowford Moor to monitor run-off rates from a Culm grassland sub-catchment

7. PROJECT APPROACH TO VALUATION

The project team identified several different values for Culm grassland of potential interest for this study:

- The present contribution of the existing Culm grasslands
- The value of Devon Wildlife Trust's contribution by its restoration work to date
- The potential value if Culm grasslands were restored to their 1900 levels
- The value of the Culm within an example water catchment
- The comparative value between Culm grassland and IMG

In addition the team identified four different spatial extents of Culm grassland to provide an insight into the value of the Culm grasslands for water storage and carbon. They are (Table 3):

Study area	Area, hectares
Existing Culm and land being restored to Culm	6,418
Area of grassland being recreated/restored by Devon Wildlife Trust	3,984
1900 Area of culm (estimated)	29,500
Culm in Wolf Catchment area, which feeds Roadford Reservoir, 2007 area (estimated)	132
Culm in Wolf Catchment area, which feeds Roadford Reservoir, 1947 area (estimated)	455

Table 3: Study areas

Species rich meadows protect Roadford Reservoir from run-off of silt

8. APPROACH TO ECONOMIC EVALUATION

It was necessary to reduce the monitoring data to a common set of parameters for the purpose of economic evaluation. For this purpose the cubic metre and the hectare (10,000 m^2) were chosen as a common basis as already noted in Table 2 i.e. m^3/ha.

The physical data must then be translated into financial values. Although there are clearly benefits from the improvement of water quality and storage, reduction in sedimentation and the capture and storage of carbon these do not all necessarily translate into separate financial values.
For example, theoretically the removal of sediment from the water running into Roadford Reservoir should be a benefit to South West Water, its shareholders and customers through reduced operational costs at the reservoir. In practice sedimentation does not represent a 'real' current cost because no steps are regarded as necessary in order to remove silt from the reservoir, nor are they regarded as likely to be necessary in its current working life. A similar argument applies to the presence or absence of phosphorus in the water emerging from Culm as compared with IMG.
For these reasons, an 'all-in' value has been taken for the value of fresh water.

9. WATER VALUES

The availability of fresh water held in the ground also presents valuation challenges. Unlike water in a reservoir or tank it is not possible to 'turn on the tap' to draw the water as and when it is required. With some reservoirs it is possible to gauge the economics of pumping costs to replenish the source, and to form estimates based on ground water resources in reducing potential pumping costs. This model is not applicable to the Culm grasslands.

Equally in some instances the ability of soils to hold water back could readily be identified as a means of flood protection for settlements and property, for example the work at Holnicote undertaken by the National Trust[5]. Again this model is not readily applicable to the Culm grasslands, yet there does remain a benefit to water retention for the following reasons:

- A more even distribution of water flow, either to reservoirs or as runoff from land during the year.
- The consequent preservation of soil resources that are therefore less subject to erosion. This has important benefits for the role of soil as a growing medium, carbon repository, agricultural resource and all the other ecosystem benefits of a functioning soil.
- A better quality of water entering reservoirs with less sediment, reducing the need for treatment and/or extending the life of the reservoir itself as well as leaving fewer by-products of treatment for safe disposal.

Several appraisals have sought to place a combined value on these benefits, and for the purposes of this study the range of values seems to start with the figure often quoted from the National Ecosystem Assessment (NEA) of £0.05/m^3. At the other end of the scale is a figure quoted for the value of raw water to South West Water (SWW) of £0.23/m^3. This latter figure is supported by the quoted trading price for water from Wimbleball Reservoir of £0.225/m^3 in the South West Water business case to Ofwat.

However, the latter figures seem to assume complete availability of the water resource – in other words it will flow when the tap is turned on. This question has already been considered for the value of water stored in peat on Exmoor moorland by reference to the Wimbleball trading price, with consideration of a range of factors. A factor of a quarter or a third seemed appropriate as an adjustment for drinking water purposes in that instance where the economic benefit arose from a more even and regular flow of water down the River Exe, which in turn would lessen the need for replenishment water to be drawn from Wimbleball Reservoir and therefore less need for replacement pumping during the winter months.

There seems to be a reasonable case for enhancing this figure where water from the Culm grasslands is feeding directly into the public water supply. This is the case for the Wolf Catchment which feeds directly into Roadford Reservoir, a key water source for supplying customers in North Devon. There is little direct evidence on which to base this judgement, but it does seem clear that a downward adjustment from the South West Water trading figure is appropriate. Equally a premium over the quoted National Ecosystem Assessment figure also seems appropriate, given the lapse of time since the derivation of that figure (in which the Consumer Price

[5] See http://ccmhub.net/case-studies/holnicote-case-studies/holnicote/ for more details and further links regarding this project

Tussocky Culm grassland holds water in the landscape

Index has risen by approximately 10%), and the greater pressure on water resources in the South West. This might point to a value of £0.12/m^3 (Water value to SWW x availability adjustment of 0.5) where there are discernible identifiable public water supply benefits, and £0.08/m^3 (water value to SWW x availability adjustment of 0.33) in other situations.
Of necessity this is a broadly-based and to some extent unempirical judgement but it does place the values in the lower half of the range between NEA and SWW trading values.

These are annual values so will in due course need to be capitalised in order to arrive at a Present Value of the water benefits. Although a little higher than the figure reported in the NEA of £0.05/m^3 these figures seem broadly reasonable given the higher costs associated with water supply in the South West Water area and general inflation since the NEA evaluation was undertaken. The challenge of capitalisation will be discussed further below.

10. CARBON PRICING

The task of carbon pricing is made somewhat easier than water valuation by the adoption of a carbon shadow price that already represents the present value of carbon storage benefits. On the basis of a shadow price of £15/tonne and the estimates presented by Devon Wildlife Trust in Table 2, the value of carbon in Culm grasslands can be placed at £2,700/ha compared with £2,250 for IMG, a difference of £450/hectare. For each £1 variation in carbon shadow price, these figures will vary as shown in Table 4.

Land use	Carbon value at shadow price of £15/tonne (£/ha)	Variation in carbon value for each £1 variation in shadow price (£/ha)
Culm Grassland	2,700	180
IMG	2,250	150
Difference	450	30

Table 4: Carbon Shadow price sensitivity to £1/tonne change

The 'availability' of carbon is not subject to the same vicissitudes as water, but its price might be regarded as more volatile. This is due to the nature of the carbon pricing calculation itself, and to the more general state of the trading economy and therefore demand for carbon credits in one form or another. Irrespective of the details of this, the price of carbon seems set to rise in the longer term. The use of a centrally-set shadow price helps to smooth this volatility and looks to the long-term economic impact and price of carbon.

11. CAPITALISATION

The choice of discount rate and period is the key question in capitalisation[6], representing the risk and security of the 'investment' as well as a desired rate of return. The process of capitalisation over fixed periods has been explained in Section 6. Most efforts to capitalise end up using the Treasury discount rate for public sector investment, which has stood at 3.5% in the near term for some time and that will be adopted here. Water and carbon benefits can be taken to exist in perpetuity[7] and it is proposed therefore to discount them in perpetuity at the Treasury rate of 3.5%. The Treasury approach is to discount for long finite periods using lower discount rates further into the future (2.5% after 10 or 20 years for example). After a period of 50 years or so the difference between a finite period and a perpetuity becomes very modest, and in any case will be offset by retaining the higher discount rate throughout.

For example the multiplier for a discount rate of 5% in perpetuity is a multiplier of 20, whereas 5% discounted for 50 years would be a multiplier of 18.256. Applied to an annual value of £100, the former would lead to a present value of £2,000 (£2000 x 5% pa = £100, the capital figure of £2,000 is never exhausted or depleted). The 50 year rate of 18.256 would lead to a present value of £1,826. The latter figure would exhaust the resource over 50 years whereas the former figure will assume it lasts forever and therefore seems more appropriate to carbon and water benefits.

[6] *Capitalisation is another way of describing the discounting of future values to a present value: the future revenues and costs are capitalized into a single present value today.*

[7] *Most cost benefit analysis is performed over a finite period, typically the expected life of the assets created. The concept of a perpetuity might best be understood by considering how much money must be invested in order to earn £10 a year interest at an interest rate of 10% forever. This would be £100.*

12. VALUES OF CULM GRASSLAND

The previous discussion has presented an approach to the choice of unit values for this appraisal and has concluded that the value of carbon should be set according to the UK Shadow Price of carbon, and the water benefits should be taken as a percentage of the value of readily available raw water to South West Water. A higher percentage for the value of water has been taken where it exists in close proximity to a reservoir, and a lower value for water elsewhere. Due to this proximity to Roadford Reservoir the Wolf catchment has been valued at the higher figure, and other Culm at the lower figure in order to illustrate this difference in approach. In the future more detailed work to distinguish and map areas for their water gathering value may be useful in this regard. The water value in both cases seeks to reflect the total benefit of the water. This leads to the following value profile per hectare for Culm grassland feeding a public water supply directly, other Culm grassland, where it is remote from a public water supply, and IMG in terms of water and carbon benefits (Table 5):

Land use	Carbon Capital	Water Annual	Water Capital	Total Capital Water and Carbon
Culm feeding public water supply	2,700	332	9,497	12,197
Culm other	2,700	222	6,331	9,031
IMG feeding public water supply	2,250	73	7,406	9,656
IMG other	2,250	49	4,937	7,187
Difference between Culm and IMG both feeding public water supply	450	259	2,091	2,541
Difference between ‘other’ Culm and ‘other’ IMG (ie not directly feeding the public water supply)	450	173	1,394	1,844
Difference between (1) Culm feeding public water supply and (2) ‘other’ IMG	450	283	4,560	5,010

Table 5: Value profile per hectare (£/ha)

The figures in Table 5 have been based on the unit values derived for water and carbon in the previous paragraphs, and the availability of carbon and water resources previously quoted from the work of Puttock and Brazier. The figure for IMG feeding a public water supply requires further comment as it almost certainly overstates the value of this water. This is because the water leaving IMG will contain more sediment and other contaminants, meaning it is less appropriate to value it at the premium rate of £0.12/m^3 which has been adopted. Given that this global figure for the value of water also represents the contribution of IMG to flood mitigation and general water flow it is probably fairer to use the ‘IMG other’ figures for general comparison. This comparison is shown in the last line of the table.

In Table 6 we can now bring these values together for our different study areas.

Study area	Area, ha	Carbon Values		Water Values
		Absolute	Marginal	Absolute
Existing Culm and land being restored to Culm	6,418	17,328,600	2,888,100	1,424,796
Area of grassland being recreated/restored by Devon Wildlife Trust	3,984	10,756,800	1,792,800	884,448
1900 Area of culm (estimated)	29,500	79,650,000	13,275,000	6,549,000
Culm in Wolf Catchment area for Roadford Reservoir, 2007 area (estimated)	132	356,400	59,400	43,824
Culm in Wolf Catchment area for Roadford Reservoir, 1947 area (estimated)	455	1,228,500	204,750	151,060

Table 6: Summary of Capital and Annual Values for Water, capital values for carbon, total capital values (£)

Notes on Table 6:

Water values for the remaining Culm area, the grassland area restored by Devon Wildlife Trust and the 1900 area of Culm have been derived from the lower price of water (£0.08/m^3) previously discussed i.e. water which does not readily find its way into the public water supply. The marginal values have been taken from the difference between Culm water and IMG based on this non-premium value.

The values for the Wolf Catchment area have been derived from the higher value adopted for water which can readily find its way into the public water supply value (£0.12/m^3).

Annual		Water Value Capital		Total Capital	
	Marginal	Absolute	Marginal	Absolute	Marginal
	1,110,314	40,632,358	11,834,792	57,960,958	14,722,892
	689,232	25,222,704	7,346,496	35,979,504	9,139,296
	5,103,500	186,764,500	54,398,000	266,414,500	67,673,000
	37,356	1,253,604	661,320	1,610,004	720,720
	128,765	4,321,135	2,279,550	5,549,635	2,484,300

13. COMMENTARY ON THE VALUATIONS

The valuations demonstrate a number of important financial aspects to the value of Culm grassland for water and carbon. For example:

- Based on the marginal value of the 1900 Culm area there has been a loss of water and carbon value of £9.7 million (marginal value of 1900 Culm minus the absolute value of Culm now).
- The work undertaken by Devon Wildlife Trust to date will potentially have added water and carbon value of £9.139 million based on its marginal value over IMG once the restoration work has taken full effect.
- The current Culm area has a marginal value of £14.723 million.

It is important to note that the reason for subtracting the absolute value of Culm today from its marginal value in 1900 is that most or all of the land that was Culm in 1900 still has some form of grassland or similar land cover today. Whilst not having the structure and capabilities of Culm, this land cover continues to work as a carbon store and to provide water benefits albeit of a lower order than the Culm it has replaced. The area of land lost to Culm is therefore still performing an ecosystem service function, and a comparison of the absolute values for Culm now and in 1900 would fail to reflect this point.

It should be noted that this study has not looked at the changes in agricultural value of the land. Valuing agricultural land, especially in an area like the Culm, is less straightforward than it might appear. A first point to note is that the market value of the land does not represent its economic value for agricultural production.

A simple way to consider the agricultural value would be to consider agricultural profits from the land and apply similar discounting methods described earlier in this paper in order to obtain a capital value. These could then be compared with the values obtained for land managed as semi-natural culm vegetation. However, the figures would need to be qualified to reflect the influence of farm subsidies, without which large areas of the Culm would probably not be commercially viable for farming. Some of these subsidies, like the Single farm Payment (or Basic Payment) can be claimed whether the land is managed for semi-natural grassland habitat or intensively managed grassland. Moreover, more targeted subsidies, like Higher Level (or Countryside) Stewardship, can only be claimed on areas being restored to semi-natural habitat and are not available for intensively managed grassland. The nature and availability of such grants is likely to change in future and will be likely to have a significant effect, but this is very hard to predict given the wide range of other factors which can also affect the value of rural land.

A further level of complexity is that the land can be regarded as productive whether or not it is managed as semi-natural culm grassland or intensively managed grassland. The latter clearly has higher agricultural productivity and related income than the former, which is typically associated with extensive and low input grazing. However, the costs of agricultural inputs such as fertilisers, pesticides, herbicides and fuel, are also much higher in the case of intensive management. Moreover, there may be premiums available for some less intensive methods of farming, such as organic beef.

And finally there are further complications regarding how to value the agricultural improvements associated with agrochemicals. On the one hand they increase the land's productivity. However, on the other hand they have a significant negative impact through all the embodied energy in their production and application, and the associated carbon emissions.

The nature and availability of agricultural subsidies is one of the many factors that influence the choice of agricultural regimes over much of the Culm. Its importance will vary from one farmer to another, being weighted with personal preferences, experience, labour and capital availability as well as the overall pattern of landholding and tenure. In some cases the support regime may be a principle driver, but this will not inevitably be the case for all farmers. Further work to examine the relative importance of asset values, support regimes and other factors with the farmers and landowners in the Culm would be a potentially valuable exercise to extend our understanding of the factors which can influence the positive management of these resources and the relative costs and benefits to society.

14. CONCLUSIONS

Undertaking this analysis has highlighted the complexity in attributing financial values to the ecosystem services delivered by Culm grassland, and the challenges that need to be addressed. It has also highlighted the importance of an inter-disciplinary approach to analysis to enable environmental organisations such as the Wildlife Trusts to explore, understand and communicate the value of their landscape scale conservation work for both people and wildlife.

This research has assessed and identified the value of Culm grassland at four different scales for their water and carbon benefits.
This study has the benefit of being based on the solid empirical work undertaken in the Culm grasslands and IMG by Puttock and Brazier, whereas the financial values applied to their physical data are derived from other studies adjusted for the purpose of this study.

The annual and capital values derived for this study are substantial, at both the unit hectare level and globally. In conjunction with the previous research to quantify the water resource and carbon storage capacities of Culm, they provide a strong case for the importance and value of continued investment in the maintenance, restoration and recreation of Culm grasslands.

Traditional breeds of cattle can convert rough species rich pasture to protein

Over the next ten years, Devon Wildlife Trust aims to restore at least 5,000 ha more Culm which, on the basis of this analysis and valuations, will more than double the Culm's water and carbon value to in excess of £20.5 million. Given that the costs to Devon Wildlife Trust of restoring and recreating this area of Culm is in the region of £2 million, the valuations indicate over a ten-fold return on this investment.

Through this analysis we have come to recognise that there is no simple formula to understanding the relative costs of investing in and managing Culm grasslands as a soft engineering approach to improving water resource management, in comparison to investment in traditional hard engineering such as water treatment works. The report highlights complexities such as:

- sedimentation does not represent a 'real' current cost to South West Water in relation to Roadford Reservoir, because no steps are regarded as necessary in order to remove silt from the reservoir, nor are they regarded as likely to be necessary in its current working life.
- whilst Culm grassland has been shown to hold considerably larger quantities of water than IMG, unlike water in a reservoir or tank it is not possible to 'turn on the tap' to draw the water as and when it is required. With some reservoirs it is possible to gauge the economics of pumping costs to replenish the source, and to form estimates based on ground water resources in reducing potential pumping costs. This model is not applicable to the Culm grasslands.

However it is important that we use this study, its findings and identified challenges as a springboard for further investigation and partnership working. The challenges of securing safe, clean water supplies and managing flood risk continue to increase. Devon Wildlife Trust's research indicates the key roles and values of wetland grassland habitats such as Culm in addressing these societal concerns. The following section identifies a number of potential next steps, which can help to address some of these issues and challenges.

15. NEXT STEPS

This study has taken the first step in placing financial value on the water and carbon benefits of Culm grassland. Of necessity it has taken a broad approach, and it is important that we build on this work with our partners to create a more in depth understanding of the role of Culm in water resource management and the delivery of the Upstream Thinking approach. Further work would be desirable in order to:

- assess the value of the specific services delivered by this habitat e.g. filtration of sediment from water, flood attenuation and water storage. This requires further in depth analysis with South West Water and the Environment Agency to understand the methodologies and data used to calculate the costs of water treatment and flood mitigation in particular settings;
- compare the capital value of the land for intensive agriculture as opposed to semi-natural Culm, to help understand the net benefits to society when we consider food production, energy requirements, carbon emission and water resource management;
- examine the policy, fiscal and funding mechanisms by which land managers might be encouraged to respond to the valuable opportunity to protect water and carbon benefits for future generations (Payment for Ecosystem Services);
- address the hydrological benefits on a more specific basis by location. This could include more accurate quantification, perhaps focusing on areas upstream of flood risk reductions, enhancements of base flows in watercourses and at water abstraction locations, and the water treatment costs to South West Water for removal of specific pollutants from drinking water; and
- develop tools, including GIS-based maps to allow a rapid appraisal of these benefits for policy appraisal purposes.

There are other ecosystem service benefits of Culm grassland and the Culm NCA, such as tourism and added value agricultural products, that were beyond the scope of this valuation study. These would also benefit from future research and analysis, to build up a more comprehensive picture of the overall value of the Culm landscape for both people and wildlife.

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