ELM Scheme Test Pilot – Natural Capital Accounts for Cholderton & Snoddington Manor Estates

Final Report

Defra, Cholderton Estate & Snoddington Manor Estate

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Disclaimer

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Document evolution

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**Minor update to reflect a correction to Cholderton Estate overhead costs*
This report is based on eftec's Version 1 - May 2019 report template

Executive summary

The purpose and the process of this Defra Test & Trial

This is a Defra Environmental Land Management (ELM) scheme Test and Trial project with the purpose of demonstrating how natural capital accounting can be used to establish a baseline for natural capital extent, condition and benefits, and measure changes from that baseline through implementing a Land Management Plan (LMP) which can be (co)funded by Defra.

It applies natural capital accounting to two farms in the chalk soils of Hampshire and Wiltshire:

- Cholderton Estate – a 1,000 ha mixed organic farm, the land management approach being driven by the owner, Henry Edmunds, a keen naturalist, who has the aim of achieving a balance between the demands of modern competitive agriculture and the preservation of the countryside, with particular focus on habitats for wildlife and plants.
- Snoddington Manor Estate – a 560 ha arable farm, which has been profitably managed through planned use of conventional inputs, mechanisation, and crop rotations, but has been acknowledged by the owner, Iain Currie, to have been at the expense of natural capital and some public benefits. Consequently, the owner is looking at alternative land management approaches.

The process of putting the accounts together and using this to inform Land Management Plans involved:

- Producing the baseline account by merging data from the Estates and elsewhere showing the significant natural capital benefits, and where maintenance of natural capital may not be enough and/or farming practices may lead to degradation of the natural capital assets (e.g., soil condition).
- Preparing a Land Management Plan incorporating the findings of the accounts, business plans and strategic priorities of the Estate owners, regulatory requirements, and the gaps / assumptions in the accounts that could point to improvements. Consequently, the Land Management Plans include actions to maintain natural capital assets (such as soil condition and biodiversity), and to reduce disbenefits such as greenhouse gas emissions and nitrate leaching from nitrogenous fertiliser use.
- Testing the impact of the Land Management Plans on natural capital assets by showing how asset values and maintenance liabilities change with the plans compared to the baseline account. Such changes also highlight which actions generate private benefits and can be financed by the Estate owner and which generate public benefits and should be financed by public money.

This process produced a natural capital balance sheet and supporting schedules that show the projected future natural capital benefits to the estates and to the rest of the society; the costs of producing these benefits and the current or committed spend on maintaining the underlying assets.

The accounts presented below should be read in the following context:

- **The accounts are based on information available**. Time to discuss information sources and assumptions with owners was limited, hence estimates have been made on the basis of the best information available. Nevertheless, accounts highlight the salient features of, and issues for the natural capital assets of each farm overtime.
- **The accounts project future benefits as continuation of current situation** (a 'static baseline'). This is due to lack of modelled projections about future environmental and other conditions. In the absence of such projections, we cannot establish a relationship between the current maintenance activities and the resulting extent and condition of natural capital assets. Therefore, we cannot conclude, in a baseline account like this, that current maintenance activity is sufficient to sustain current benefits.
- **Nevertheless, some future changes are incorporated into the baseline account, and it serves the purpose of being a baseline from which changes, for example, due to a land management plan, can be measured**. There are many users of / pressures on the natural capital assets that are beyond the control of a single business, specifically climate change. Such chances should be incorporated into LMPs even if their implications cannot be wholly captured in the balance sheet. We have incorporated some assumptions of the impacts of climate change to illustrate possible effects on natural assets and benefit levels, however this should not be taken as an accurate forecast.
- **Many significant benefits (but not all) are estimated in monetary terms**. Biodiversity presents the most significant benefit that is difficult to evaluate adequately in monetary terms, however a proxy based on the Defra biodiversity metric has been included to illustrate the potential scale of biodiversity benefit, whilst acknowledging the shortcomings of this approach.

Results for the Cholderton Estate

The Cholderton Estate natural capital balance sheet is shown in Table S.1.

Table S1: Natural capital balance sheet for Cholderton Estate

Confidence	Summary of asset values (Present value over 60 years)[1] Base year: 2020	Baseline Plan Private £'000	Baseline Plan Public £'000	Future LMP Private £'000	Future LMP Public £'000	Difference Private £'000	Difference Public £'000
	Assets						
●	Food production [2]	5,400		5,400		-	-
●	Other - Seed production [3]	300		300		-	-
●	Timber production & grants [4]	100		100		-	-
●	Renewable energy [5]	-		4,800		4,800	-
●	Woodland burials [6]	600		600		-	-
	Climate regulation impacts: [7]					-	-
●	C sequestration woods/hedges [7a]		3,700		3,700	-	-
●	C sequestration in soil [7a]		5,200		10,300	-	5,100
●	Farming GHG emissions [7b]		(5,500)		(5,500)	-	-
●	Air quality benefits [8]		800		800	-	-
●	Water quality benefits [9]		500		500	-	
●	Recreation [10]		1,200		1,200	-	-
●	BPS & Agri-env income [11]	7,300		7,300		-	-
	Total gross asset value	**13,700**	**5,900**	**18,500**	**11,000**	**4,800**	**5,100**
●	Biodiversity [12]		> 115,300		> 115,300		
	Indicative asset value	**13,700**	**> 121,200**	**18,500**	**> 126,300**	**4,800**	**5,100**
	Liabilities						
	Natural Capital Maintenance Costs						
●	Legal obligations [13]	(700)		(700)		-	-
●	Other maintenance		(7,300)		(7,300)	-	-
	Other Business Costs						
●	Overheads [14]	(11,700)		(11,700)		-	-
	Total liabilities	(12,400)	(7,300)	(12,400)	(7,300)	-	-
	Total net asset value	**1,300**	**> 113,900**	**6,100**	**> 119,000**	**4,800**	**5,100**
	Non-natural capital: [15]						
●	Property & wayleave	800	-	800	-	-	-
	Overall Economic Value	**2,100**	**> 113,900**	**6,900**	**> 119,000**	**4,800**	**5,100**
	Benefits from natural capital (non-monetised)						
●	Insect species abundance	18 bee species 40 butterflies 740 moths		18 bee species 40 butterflies 740 moths		Sustained (No Change)	
●	Wild bird species	137 species		137 species		No Change	
●	Number of wild flowers	+70		+70		No Change	

Notes: The numbers above refer to notes explaining the key assumptions behind the calculations. These can be found in Section 3.4. Confidence ratings for benefit and cost estimates are rated as high (green), medium (amber), low (red), see Annex 1.2 for definitions.

Excluded from this account are:

- **Water quantity** – soils and woodland play an important role in regulating the flow of water and can contribute towards mitigating flood risks and sustaining water supply in periods of drought. This is a potentially significant benefit in the baseline or the future LMP but, to be properly evaluated, requires hydrological modelling of the catchment, which is beyond the scope of this account.

Interpreting what the account shows

It shows that the Estate produces public and private benefits in excess of the BPS & agri-env income it receives but without that payment, private income would not be sufficient for a sustainable business in the baseline case and would be around break-even in the future LMP case. Cholderton delivers a range of public benefits, but the most significant is the species diversity and habitat that is provided by the Estate. This biodiversity benefit cannot be evaluated precisely, but the proxy method used in this account provides an indication of its value.

Biodiversity is a very significant benefit at Cholderton but difficult to link to provision of private and public benefits and evaluate in monetary terms. The diversity of species at Cholderton is unique, "The range of species recorded on Cholderton is quite remarkable. Mr Edmunds has records of 1500 species including many rare and declining ones, which have been verified by the various conservation bodies" (Cross, 2020). The variety of plant and animal species is a key feature of the Estate, and it is this uniqueness that presents a particular challenge to valuation.

For the purposes of providing an indication of value, likely costs of delivering a 'biodiversity unit' (Defra (2019) have been used to estimate the cost of reproducing this habitat elsewhere. This follows the 'replacement cost' approach to value a benefit and has been estimated based on an anticipated market price of a biodiversity unit in a UK market context. However, it should not be seen as a definitive valuation. It does not capture the complex ways in which biodiversity supports all benefits provided by nature, and some of the contribution of biodiversity to those benefits may already be captured in the valuations already included in the account. So, there will be some undervaluation and some double counting here, but we are testing this approach for the benefit of discussion, and to provide an order of magnitude appreciation of the relative importance of biodiversity.

Soil is a key natural capital asset underpinning many benefits. Soil is an asset that takes many years to form and supports; food production, carbon sequestration, water quality, biodiversity, and resilience to future pressures such as climate change. Elements of these soil benefits that are shown in the account include:

- **Carbon sequestration**. The Estate's approach to soil management is based on preserving and building organic matter and hence has significant potential to sequester more carbon. Due to limited data this is difficult to forecast and evaluate accurately, but a reasonable potential range of sequestration benefit is around £5 to £10 million (low baseline estimate increasing soil organic matter by 1% over 50 years, and the high estimate by 2% over 50 years). These estimates are produced to illustrate the potential for further benefits and the feasibility of these targets is to be tested through further soil sampling and specialist advice.

- **Resilience to climate change**. Changing climate will affect the current provision of private and public benefits provided by natural capital assets. Assets that are in good condition are more likely to be resilient to such changes and hence could uphold benefit levels in the face of adverse pressures. The most significant threat in this area over the next 60 years is more frequent and severe droughts. Cholderton soil and land management approach includes building soil organic matter, eliminating the use of pesticides/herbicides, the use of deep rooting grass leys that all improve soil structure and resilience to drought. Empirical experience from Cholderton indicates that the Estate has been less impacted than neighbouring farms by recent droughts (particularly in 2018), avoiding the need to buy in extra forage and feed during the prolonged periods of drought. Impacts of drought have been modelled as additional costs (for bought in livestock feed) but have assumed to be mitigated by 80%. Consequently, the reduction in net food income is relatively small (amounting to less than £10 k over 60 years).

GHG footprint of farming is material and is comparable to woodland or soil carbon sequestration. The current land management at Cholderton avoids or minimises many farming disbenefits such as water pollution from nitrate leaching, and air pollution and greenhouse gas emissions from the use of inorganic fertilisers. However, the main farm system disbenefit is greenhouse gas emissions (£5.5 million over 60 years), mainly from enteric fermentation and decomposition of manure from livestock. A level of emissions from livestock is unavoidable, however the Cholderton approach includes sainfoin in the grazing diet which can reduce enteric fermentation emissions by around 12% and this benefit has been included in the emissions figure estimated.

Other features. The baseline case reflects that the farm business currently makes 55% gross margin and 33% earnings before interest and depreciation. However, this includes BPS and agri-environment income, and the business relies on this income plus income from non-natural assets (rents & wayleave) to cover business overheads and make an overall net profit. In the future LMP case this situation improves through the installation of a solar farm. Since solar farms use land that can be used instead of (or alongside) other farming activities, this benefit is included in the natural capital balance sheet.

For Cholderton Estate – we recommend that the Estate:

- Seeks assistance in measuring existing soil organic carbon levels and seek advice on what current evidence suggests is a realistic rate of carbon sequestration that can be attributed to Cholderton practice;
- Regularly reviews the latest forecasts of climate change projections and understands what these mean for their practice;
- Follows developments in dietary approaches to the reduction of enteric fermentation emissions from livestock, and considers dietary changes where appropriate and feasible;
- Considers other opportunities identified in the course of this test pilot project, (for woodland restoration/creation and reductions to fossil fuel use in farm operations) and develops

specific schemes for improvement and inclusion in future LMPs, and

- Explore the opportunities through emerging markets for carbon credits; biodiversity net gain and others that may develop in addition or instead of public money.

Results for Snoddington Manor Estate

The Snoddington Manor Estate natural capital balance sheet is shown in Table S.2.

Table S2: Natural capital balance sheet for Snoddington Manor Estate

Confidence	Summary of asset values	Baseline Plan		Future LMP		Difference	
	(Present value over 60 years)[1] Base year: 2020	Private	Public	Private	Public	Private	Public
		£'000	£'000	£'000	£'000	£'000	£'000
	Assets						
●	Food production [2]	8,800		8,500		(300)	-
●	Timber production & grants [3]					-	-
●	Renewable energy [4]	1,600		1,600		-	-
	Climate regulation impacts: [5]					-	-
●	Carbon sequestration [5a]		1,300		1,300	-	-
●	GHG emissions [5b]		(2,200)		(1,600)	-	600
●	Air quality benefits [6]		300		300	-	-
●	Water quality [7]		-		-	-	-
●	Recreation [8]		1,500		1,500	-	-
●	BPS income [9]	2,700		2,700		-	-
	Total gross asset value	**13,100**	**900**	**12,800**	**1,500**	**(300)**	**600**
●	Biodiversity [10]		2,600		2,600	-	-
	Indicative asset value	**13,100**	**3,500**	**12,800**	**4,100**	**(300)**	**600**
	Liabilities						
	Natural Capital Maintenance Costs						
	Legal obligations [11]						
●	Other maintenance	(100)	(2,700)	(100)	(2,700)	-	-
	Other Business Costs						
●	Overheads [12]	(10,200)		(7,100)		3,100	-
	Total liabilities	**(10,300)**	**(2,700)**	**(7,200)**	**(2,700)**	**3,100**	
	Total net natural asset value	**2,800**	**800**	**5,600**	**1,400**	**2,800**	**600**
	Non-natural capital: [13]						
●	Property & wayleave	200		200			
	Overall Economic Value	**3,000**	**800**	**5,800**	**1,400**	**2,800**	**600**

Notes: The numbers above refer to notes explaining the key assumptions behind the calculations. These can be found in Section 4.4. Confidence ratings for benefit and cost estimates are rated as high (green), medium (amber), low (red), see Annex 1.2 for definitions.

Excluded from this account are:

- **Water quality** - impact of herbicide and fungicide use, due to a lack of a methodology to adequately evaluate the impacts of use.
- **Water quantity** – soils and woodland play an important role in regulating the flow of water and can contribute towards mitigating flood risks and sustaining water supply in periods of

drought. This is a potentially significant benefit in the baseline or the future LMP but, to be properly evaluated, requires hydrological modelling of the catchment, which is beyond the scope of this account.

Interpreting what the account shows

Based in the figures supplied, Snoddington is a more profitable farm than Cholderton (slightly higher income from an area that is less than 60% of Cholderton), and it generates a modest level of public benefits. The proposed management plan is self-financing in that its main impact is to reduce overhead costs, whilst reducing nitrate and energy use, thereby reducing GHG emissions. There is potential to provide further public benefits at additional cost, requiring further actions and change in land use but these are likely to require public funding and are not included in the LMP.

Public benefits are modest, with estimates included for; carbon sequestration and air pollution removal benefits of woodland, recreational value of public rights of way, and some biodiversity value (grass margins, hedgerows, wildflower margins around the solar park, creation of a chalk down meadow). These benefits are partly offset by greenhouse gas emissions from farming (mainly fertiliser use, but also energy use). In addition, there may be other disbenefits from fertiliser, herbicide and fungicide use but these are difficult to evaluate without further information.

Key risks and opportunities for Snoddington are the following:

Biodiversity. "Intensive arable farming on the chalk [at Snoddiington] has resulted in large scale loss of biodiversity. Hedgerow planting, an area of downland creation, wildflower areas, field margins, pollen and nectar and bird seed plots provide wildlife habitat across the farm. Whilst important factors in helping 'hold the line', they will not bring about the reversal of wildlife declines which is so desperately needed" (Cross, 2020).

As for the Cholderton Estate account, we illustrate a replacement cost approach to valuing biodiversity (using the cost of purchasing a biodiversity unit – (Defra 2019). In this case, the value is significantly lower compared to Cholderton given the extent and condition of the land. While this estimate is only illustrative (and could double count with some of the other benefits included in the accounts), it shows that the farm has great potential to reverse declines and restore wildlife populations, but a significant change in approach is required to achieve this.

Soil. There is uncertainty around the sustainability of arable soils.

- **Sustaining crop yields.** The risk is that the cropping plan and use of inputs do not sustain soil structure, organic carbon levels, and resilience to future pressures such as climate change. The benefits of food production in the balance sheet assumes that soil condition is maintained. Without more data it is difficult to quantify this risk accurately, but as an illustration, if the production forecast assumed that crop yields could fall by 1% year on year from 2030, the impact on food benefit would be around £1.6 million over the period to 2080.

- **Resilience to climate change**. More frequent and severe droughts is a climate change risk that will affect Snoddington as it does all farms. The Snoddington approach to soil management does not aim to build organic matter and improve soil structure (compared to Cholderton), and hence suggests a lower level of resilience to climate impacts. The same scenario of drought has been used to estimate possible crop reductions (a range of 2% to 10% yield reduction in drought years, but an average annual equivalent applied assuming 6% reduction every ten years). It has been assumed that Snoddington soil assets provide no mitigation to these impacts. On the upside, investment in soil health will not only improve resilience but also provide carbon sequestration benefits, which due to lack of evidence have been assumed as zero.

Public disbenefits from use of artificial fertilisers, herbicides, and pesticides. Artificial fertilisers have a higher GHG impact than organic manures (disbenefit of over £2 million), so minimising use or switching to organic fertiliser will reduce GHG emissions. While it has not been possible to quantify the direct impact of using herbicides, and pesticides on water quality and biodiversity, these will come under increasing scrutiny and opportunities to utilise alternative approaches should be considered.

For Snoddington Manor Estate – we recommend that the Estate:

- Seeks assistance in measuring existing soil organic carbon levels and seek advice on what current evidence suggests is a realistic rate of carbon sequestration that can be achieved;
- Implements a 'soil protocol' that can be used to assess current soil health and quantify the effect of any changes over time. Such a protocol could include soil biology (e.g., organic matter and earthworm count), physical characteristics (e.g., structure and texture), chemistry (e.g., pH, macro-nutrients and micro-nutrients) and water permeability. The aim should be to understand the factors that underpin soil condition and productivity in the long term;
- Regularly reviews the latest forecasts of climate change projections and understands what these mean for their practise;
- Explores options for making further reductions in greenhouse gas emissions from fertiliser use. This could include avoiding fertiliser use in the first instance (e.g., through regenerative or organic farming, or the greater use of fertility building crops) and if fertiliser is used, using less, using it more efficiently and using lower impact fertilisers (e.g., avoiding urea and utilising manure if it is available). The latter group of actions could also lead to financial cost savings for the Estate;
- Explore the options to reduce fossil fuel use. Currently the Estate uses around 45,000 litres of diesel and 40,000 kWh of grid electricity. The LMP scenario shows a reduction of 6,300 litres in diesel use through less intensive cultivation. The Estate could explore options to reduce fossil use further
- Considers other opportunities identified during this test pilot project, (for woodland restoration/creation and reductions to fossil fuel use in farm operations) and develops specific schemes for improvement and inclusion in future LMPs, and
- Explore the opportunities through emerging markets for carbon credits and biodiversity net

gain and others that may develop in addition or instead of public money for funding sequestration benefits. Snoddington has some capacity for new woodland creation and should consider schemes which may enhance income from carbon sequestration.

Lessons and Recommendations for the Defra ELM Test & Trial Programme

The test shows that the proposed accounting process works, namely, we can:

- Produce a baseline natural capital balance sheet to highlight the current extent and condition of natural capital and value of various benefits;
- Use this information to inform decisions on proposed Land Management Plans, and
- Show the impact of the plans on future natural capital benefits and liabilities by producing a natural capital balance sheet showing the changes.

While there are gaps and caveats as discussed above, the accounting process leads to new connections between farming practice and private and public benefits from natural capital, and the accounting structure allows for comparisons to be made across scenarios and over time. Therefore, we conclude that natural capital accounting can be used as a monitoring and evaluation tool, tracking the latest performance of natural capital condition and benefits against the proposed LMP.

The process makes it is possible to identify which actions in the LMP the Estate owner can do with no or little added cost, and which they will need public money (or, when more widely available in future, private finance) to deliver. In fact, in the case of the Snoddington Estate, the LMP could include actions that will deliver both financial benefits (cost savings) and environmental improvements.

More engagement from the land manager helps create an account that is better at reflecting the current situation and future plans and plans that have buy-in and hence higher likelihood of success to delivery. More engagement will come when ELM becomes more of a reality. Therefore, we recommend that Defra -

- Supports the process of natural capital accounting to show the current baseline and possible improvements for which public money is sought, both at the beginning of the application process and throughout as a monitoring and evaluation tool;
- Improves knowledge and capacity of farmers to access reliable methods of soil carbon measurement and monitoring;
- Requires better recording and monitoring of production and natural capital maintenance costs, and
- Enables incorporation of climate change risks into LMP by providing easier interpretation of climate change projections for natural capital assets and land use and management at the farm level. This will allow incorporation of such risks into all public benefit delivery objectives of ELM scheme and is also supported by the recommendations of the Climate Change Committee (2020).

Contents

Abbreviations & Acronyms

Defra	Department for Environment, Food and Rural Affairs
ELM	Environmental Land Management scheme
LMP	Land Management Plan
NCA	Natural Capital Accounting
NCBS	Natural Capital Balance Sheet
NVZ	Nitrate Vulnerable Zone
NWEBS	National Water Environment Benefit Survey
ORVal	Outdoor Recreation Valuation tool
SOM	Soil Organic Matter
UKCEH	United Kingdom Centre for Ecology and Hydrology
WFD	Water Framework Directive

1.Introduction

Natural capital is that part of nature which directly or indirectly underpins value to people, including ecosystems, species, freshwater, soils, minerals, the air, and oceans, as well as natural processes and functions (Natural Capital Committee 2019). These natural assets are essential to the delivery of many benefits upon which we all rely and understanding how these benefits depend upon the health of natural capital (both quantity and quality) is key to the sustainable management of these assets in the long term.

Natural capital accounting is a systematic way of bringing together environmental, financial and economic data to understand the impacts and dependencies of an organisation on nature. The accounting outputs are based on the familiar format of financial accounts (balance sheet and income statement) so that all information relevant to decision making can be considered together. In this application, we produce a **Natural Capital Balance Sheet** (NCBS) for two farming Estates, which is based on the Corporate Natural Capital Accounting framework produced for the UK Natural Capital Committee (eftec et al, 2015).

An NCBS shows the benefits that natural capital assets provide to the organisation that owns or manages the assets and to the rest of society. Some of these latter benefits are so called public goods[1]. NCBS also shows how much the organisation spends on maintaining the natural capital assets to fulfil its statutory obligations or voluntary commitments – this spending is called 'liabilities' which differ in definition from a financial balance sheet.

The NCBS is read to answer the key question of whether the organisation is providing sufficient maintenance of natural capital assets so that they can keep on providing the benefits identified. No NCBS is complete as we lack some elements of scientific and economic data to provide a complete coverage and as the account often focuses on material impacts and dependencies only. Therefore, it is not always possible to link maintenance actions to benefit provision into the future – and the accounts presented here are not exceptions to this. The interpretation of the balance sheet needs to be mindful of this - some of the key messages from the accounts can indeed be based on what is not possible to cover in quantitative terms. For example, it may not be possible to fully quantify the impact of climate change risks, but different assumptions about such impact to inform adaptation actions.

The NCBS can also be used to test different scenarios about the baseline (changes over time without any additional or different action) and the actions planned (in this case, as part of a Land Management Plan – LMP). This is what we have done for this Defra Environmental Land Management (ELM) Scheme Test & Trial project. Three outputs were produced for each test Estate (Cholderton and Snoddington Manor):

- **A baseline Natural Capital Balance Sheet** for each Estate, which assumes existing land management practices will continue, and shows the current state of natural capital on each Estate, the benefits provided and their economic value. As far as existing information allows, future changes (such as committed farm management changes and climate change) have been included in the baseline and future LMP scenarios;

[1] In economics, a public good is a benefit which is both non-excludable (meaning everyone can benefit from it, such as the climate regulation benefits of carbon sequestration) and non-rival (meaning it is not consumed by one user thereby preventing another from enjoying the benefit, for example amenity of landscape).

- **Land Management Plan** for each Estate, which shows the land management changes that could be implemented for each Estate, developed in consultation with the estate owners. The more engaged the owners and land managers are in this process, the more realistic the LMP will be with more chance of succeeding. These have been used by eftec to prepare the accounts for each Estate, and
- **A future Natural Capital Balance Sheet** for each Estate – that shows the implications of LMP for the asset values and liabilities of each Estate.

This report presents the work in the following sections:

- Section 2 presents the process of putting a natural capital balance sheet together – with examples of templates used and detailed methodology presented in Annex 1;
- Section 3 presents the natural capital balance sheet for Cholderton Estate together with key messages and implications for land management;
- Section 4 does the same for Snoddington Manor Estate, and
- Section 5 presents the lessons learnt and recommendations for Defra ELM scheme.

The process and accounts in this report will be presented in several stakeholder workshops to share the experience beyond the two pilot Estates and receive feedback from the participants to submit a final set of recommendations from this Test & Trial.

2. Method – using natural capital accounting for ELM scheme delivery

This section summarises why the Natural Capital Balance Sheet is designed the way it is; the process of preparing it and how it can contribute to the decision about how much public money to pay for which public goods and how to monitor the outcomes of such payments.

2.1 The purpose of a Natural Capital Balance Sheet

The aim of natural capital accounting is to make visible the relationship between natural capital assets (their extent, condition and location), and the provision of benefits (public and private) and their value to society. This occurs through a set of complex 'logic chains' of natural assets, the ecological functions they perform, the flows of ecosystem services provided, and the benefits that are provided to people as demonstrated in Figure 2.1.

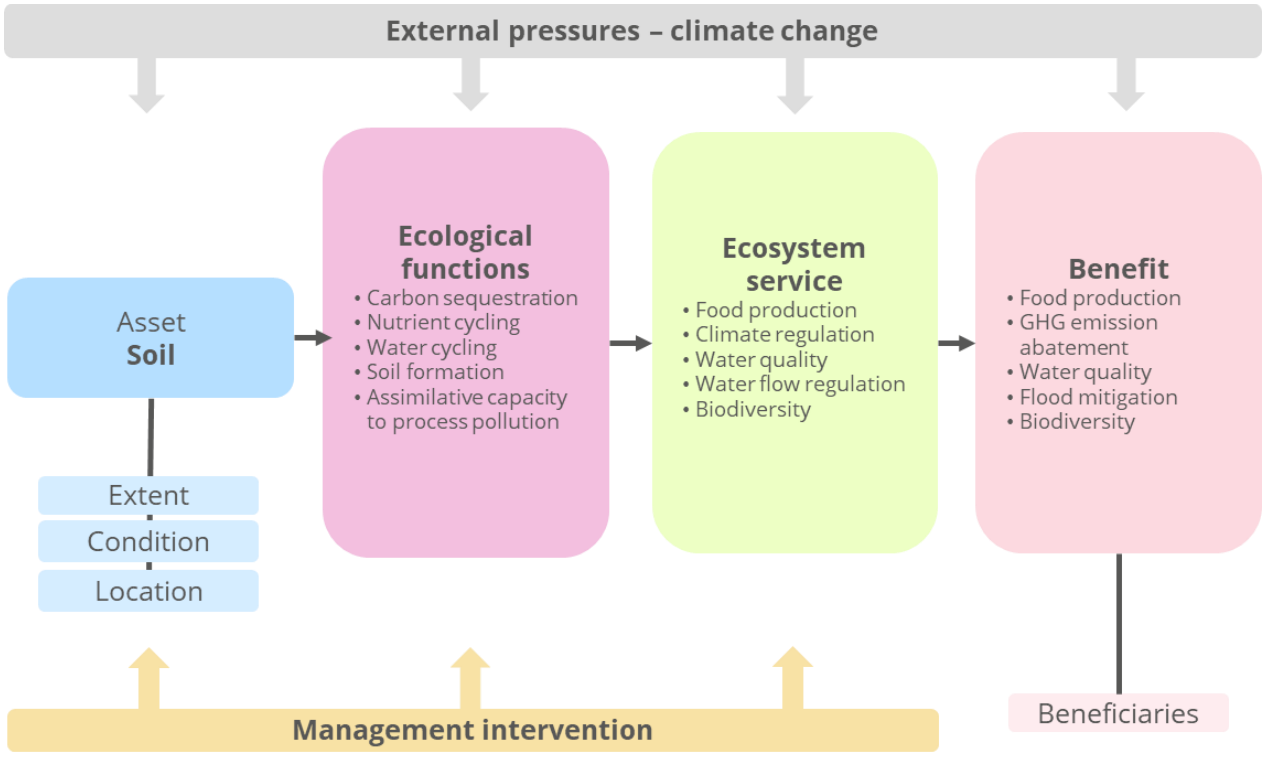

Figure 2.1: Logic chain of natural capital assets and their benefits.

The figure shows an example of soil as a natural capital asset, which performs numerous ecological functions (such as nutrient cycling), which in turn provides several ecosystem services (such as food production). These services are of benefit to people, and methods of economic valuation are applied to value these benefits. Logic chains simplify relationships that are often highly complex, and links of the chain are reported separately in natural capital accounting in:

- **Asset register** – stock of natural capital assets, and available information about their condition. Where possible, and definitely for more comprehensive accounts, a risk register is also produced to identify environmental and other risks that need to be considered;
- **Physical flow accounts** – showing ecosystem services provided in biophysical metrics that are relevant to measuring each;
- **Monetary flow accounts** – showing the economic value of the benefits to people;
- **Maintenance cost schedule –** showing the cost of maintenance activities; and
- **Natural capital balance sheet** – summarising the monetary flows and presenting them together with the financial costs of producing the benefits and costs of maintaining the assets.

The important point is that these logic chains are used to identify the most significant (or 'material' to the business and nature) benefits that are dependent upon a particular natural asset type. In this case soil provides key benefits of; food production, greenhouse gas emission abatement (via carbon sequestration), water quality (through filtration), flood mitigation (through water flow regulation) and biodiversity (as an asset that supports an ecological system). Maintenance activities are management interventions (Figure 2.1), which may be undertaken (such as adding organic matter to improve soil structure, organic content, and resilience) in response to external pressures (such as climate change).

The NCBS presents asse values per benefits provided because it is the benefits that are valued, and many assets contribute to the provision of each benefit making it difficult to apportion benefits to individual assets. However, the reader should remember that benefits are crucially dependent upon the underlying asset, and hence demonstrate the importance of monitoring, measuring, and maintaining asset extent and condition in order to sustain benefits in the long term.

Another way of presenting the design of NCBS is to focus on the management questions each supporting schedule can answer as shown in Table 2.1.

Table 2.1: The use of natural capital balance sheet in decision making

1	What natural capital assets does the business own, or manage, or depend on?	**Natural Capital Asset Register**: Registry of all natural capital assets owned / managed / dependent on
2	What flows of benefits do the assets produce, both for the business and for wider society?	**Physical flow account**: Benefits measured in biophysical metrics
3	What is the value of the benefits and to whom do they accrue?	**Monetary flow account:** Benefits measured in monetary terms: data from markets (and financial accounts of the business) and the literature, and where monetary data is lacking, measured in other indicators and qualitative narratives
4	What does it cost to maintain the natural capital assets and the flows of benefits?	**Maintenance costs schedule:** Relevant activities and their costs
5	What is the net impact of the business on natural capital?	**A natural capital balance sheet**: Sum of natural capital benefits over time minus the cost of maintaining the natural capital assets in a condition that generates the benefits.

It is also often not possible to cover every asset, every benefit and cost. There is never sufficient understanding and physical and/or economic data to reflect the complexity of nature and our impacts on it. Also, there are rarely resources to provide such a complete analysis.

Furthermore, decision makers often need to prioritise what is 'material' to the business and the nature – see how we define materiality in Section 2.2.3. The key is transparency: the accounting process and report must show clearly which assets, benefits and costs are included; which are excluded from the scope of the account and why (e.g., due to no data being available or the items is deemed not material), what assumptions had to be made to fill the data gaps and what the implications of all these decisions are likely to be on the numbers included in the balance sheet.

2.2 The process of producing a natural capital balance sheet

2.2.1 *Overview of the process*

In simple terms the natural capital accounting process takes data inputs, processes this data to produce intermediate results which are used to compile the main output, the natural capital balance sheet. The process is shown in Figure 2.2. In practice there is a high degree of iteration between the key elements. Firstly, the asset register gives an indication of the various land uses and major classes of natural capital assets in the boundary of the account. This helps inform which assets may be material to the analysis and which may be considered negligible. The materiality assessment reviews the major natural capital assets and their benefits, highlighting those benefits that are significant for the analysis, those that are material but that cannot be evaluated due to a lack of data or adequate evaluation methodology, and those that may be excluded without compromising the relevance and accuracy of the output.

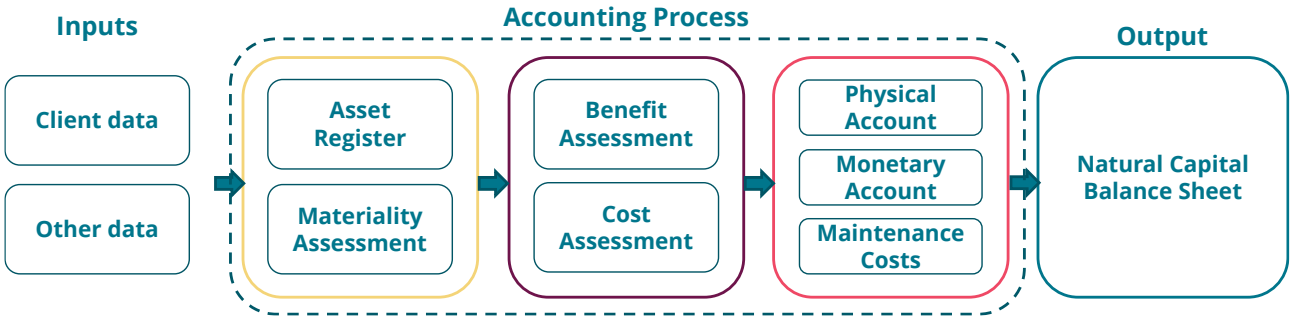

Figure 2.2: Outline of the Accounting Process

The asset register and materiality assessment are used to set the scope of the benefits and costs to be included in the account, and hence set the requirements for the input data required (both client data and other data). Once the required data is collected the most appropriate methods for evaluating benefits and costs are used to produce results. These results are compiled in three types of account; a physical flow account which records the bio-physical output of each benefit (e.g., tonnes of food produced, or number of recreational visits to a site), a monetary flow account which records the monetary value of benefits (e.g., value of food produced, or value assigned to recreational visits), and a maintenance cost schedule, which captures the costs of maintenance activities required to sustain the natural capital asserts. Finally, all these results are presented in the natural capital balance sheet to provide a clear overview of the value of natural capital assets and liabilities.

Asset values and liabilities are not static over time; however, lack of information about future conditions often means we cannot forecast future changes to the baseline account. For example, predicting the impact of climate change on crop yields is particularly challenging. Other changes may be more predictable, for example, the carbon sequestration profile of new woodland creation over a 60 year time horizon.

The accounting period needs to be long enough to adequately capture the asset life times and the impact of land management plans. For this purpose, the accounts here are prepare over 60 years (i.e., to 2080). All figures are 60 year present values discounted at HM Treasury discount rates to express values in 2020 terms (HM Treasury, 2020). Benefits and costs are forecast by each year for the time horizon, and an Excel™ model was created to allow for the variation of outputs based on parameters and assumptions that may vary these outputs overtime.

2.2.2 *Collecting data*

A simple spreadsheet was used to capture the physical outputs, monetary information, and costs for each farm (see Annex 1:) including:

- Scope of the account for each estate (i.e., the assets, benefits, and costs to include);
- The natural assets of the Estate (capturing both quantity and quality);
- The benefits and measures of their physical outputs;
- Information to value these benefits in monetary terms;
- Activities/costs necessary to maintain natural assets in healthy and productive condition, and
- Details of the trends and pressures that may vary these benefits and costs over time to help with projecting future changes including:
    - Soil management practices (e.g., to increase soil organic matter overtime);
    - Climate Change (in particular, impacts of drought and floods to productivity);
    - Tree planting (plans to increase tree cover), and
    - Farm efficiency & GHG reductions (e.g., plans to reduce fossil fuel use).

Much of the data is provided by the farm (such as food output and value, renewable energy output, business costs and activities carried out to maintain natural assets). Some data is sourced externally, (e.g., values for air pollution removal or, recreational visits and value). All general and farm-account specific data sources used are reported in References.

2.2.3 *Materiality assessment*

The first step, once initial data is collected, is to conduct a materiality assessment together with the Estate owner and their team. What is 'material' is what would make a difference to the land management decisions – and it could be material for the nature or material for the business. The Natural Capital Protocol (CC, 2016) offers useful guidance, defining an impact or dependency as, "material if consideration of its value, as part of the set of information used for decision making, has the potential to alter that decision". In this project

we have used the criterion of capacity to alter decision making as the determining factor for deciding if an item is material.

In this materiality assessment, we identify the land area/boundary, assets, benefits, and natural capital maintenance activities (see Table 3.3 and Table 4.3 in sections 3 and 4). In this case, maps of each Estate were available, which provided clear spatial boundaries, and a simple breakdown of the area by land cover type. Each owner also provided their latest farm accounts/plans, which was used to produce a generic list of likely benefits which may be material, and which may be material but not possible to include in the accounts due to lack of data.

To provide a total view of land management benefits, some benefits related to non-natural assets have been included in the accounts (such as rental income) but shown separately to benefits that are directly dependent on natural capital assets.

2.2.4 *Asset Register*

The next step was to compile the asset register which analysed the area of each Estate by major land use type. Both owners had a ready breakdown of their land by broad land cover type. For this study, the main broad land cover types were used as the basis of the asset register (Table 2.2).

Table 2.2: Outline of Asset Register Quantity

Major Land Use Type	Area (ha)
Arable	
Modified Grassland	
Semi-natural grassland	
Heath& Shrub	
Woodland - coniferous	
Woodland - broadleaf/mixed	
Freshwaters	
Wetland	
Other (inc. sealed surface)	
Total	

2.2.5 *Physical Flow Account*

The physical flow account shows the flows of the benefits provided by natural capital assets in biophysical metrics relevant to each benefit. This information can be used to quantify and monitor the changes in benefit levels produced overtime in the baseline account and due to the changes in land management as presented in the Land Management Plan. Such changes provide an indication of natural capital productivity and health.

The outputs, their physical measures and baseline estimates of output were derived from farm plans and discussions with the estate owners. The physical outputs for provisioning benefits were obvious to define and measure, however some of the other public outputs (such as recreation) required some guidance and input from eftec. Typical outputs and their measures are summarised in Table 2.3 and further detail is provided in Annex 1.

Table 2.3: Methods for the Evaluation of Physical Outputs

Benefit (Natural Capital Assets of the Estates)	Physical Measure and Method of Estimation
Food & other production (Soil, Water, Biodiversity)	Physical output defined and estimated from farm plans. For example: • Tonnes of crop by type • Heads of livestock • Weeks of grazing let
Timber production (Soil, Trees, Biodiversity)	Measured in cubic metres per year
Renewable energy (land)	Expected annual solar output generation in MWh (supplied by landowner)
Climate regulation – Greenhouse gas sequestration and emissions (Soil, Trees)	CO_2 equivalent sequestered by and stored in the following assets: • Woodland sequestration based on average UK woodland sequestration rates • Soil sequestration Physical flows of greenhouses gases (measured in tCO_2e) for the following: • Fertiliser use - emissions of nitrous oxide at average UK rate per kg applied converted to tCO_2e • Manure use – emissions at average UK rate of CO_2e per kg applied • Livestock enteric emissions – average methane emissions per head of livestock by type converted to tCO_2e • Farm operations emissions – standard tCO_2e emissions per type of energy/fuel consumed
Air Quality (Trees)	Quantity of PM2.5 removed by woodland (kg/year), estimated from eftec & UKCEH (2019).
Water quality	Surface water – The WFD condition of the River Bourne waterbody.
Recreation (Landscape, Biodiversity)	Number of annual visits estimated from ORVal[2] modelling tool, based on public rights of way identified.
Biodiversity (part of natural capital assets but also a benefit in its own right)	Defra Biodiversity Metric units were assessed as a high level desktop analysis of the current Estates' land type and condition. The biodiversity units attributed to each Estate where the difference between the units for the current state of the Estate and a counterfactual case of intensive agricultural production. In addition, various measures were used to assess condition, based on available information, such as: • Area of habitat created/maintained for biodiversity by type • Species counts where available

2.2.6 *Monetary Flow Account*

The monetary flow account calculates monetary values for the flows of the benefits provided by natural capital. Some benefits are valued using market prices (typically provisioning benefits like food production), whilst others use methods such as avoided health costs (e.g., for physical health benefits of air pollution removal), or welfare values (e.g., for recreational walks). In this account, we also trial a 'replacement cost' approach for the biodiversity benefits – even though there could be some double counting between this and the contribution of biodiversity to the provision of other benefits. The list of methods used by benefit is shown Table 2.4 and further details is provided in Annex 1.

[2] Available at: https://www.leep.exeter.ac.uk/orval/

Table 2.4: Methods for Monetary Evaluation

Benefit	Monetary Method of Evaluation
Food & other production	Value based on farm plan income less variable production costs. Other production from land based on farm plan income less variable production costs.
Timber production	Output valued at farm plan income assumptions.
Renewable energy	Monetary value calculated on contract terms of supply.
Woodland burials	Specific benefit for the Cholderton Estate and valued on farm plan income less variable costs.
Climate regulation	All flows (sequestration and emissions) valued at the BEIS published schedule of non-traded value of carbon by year (BEIS 2020). These values are based on the marginal costs of carbon abatement for the UK established in 2010[3].
Air Quality (Pollution removal)	Avoided health costs arising from PM2.5 removal by woodland, evaluated for the local authority of Wiltshire (eftec & UKCEH 2019)
Water quality	Surface water - Indicative benefit is based on National Water Environment Benefit Survey (NWEBS) values for the River Bourne water body, allocating a value for avoiding deterioration to existing WFD condition (moderate). Value attributed to Cholderton for the organic benefits of farming on water quality is based on the proportion of the water body (c 1km) that flows through the Estate, compared to the total water body length (47km). Snoddington land management entails significant use of artificial fertiliser & sprays, and it is difficult to predict the impact of these inputs without more data and hydrological modelling. Therefore, while no public disbenefit could be calculated, it is clear that no benefit to maintaining current quality can be attributed either. Therefore, there is no value associated with water quality for Snoddington. Groundwater - Both farms are in a Nitrate Vulnerable Zone (NVZ). Previous account for Cholderton (eftec, 2018) showed that diffuse pollution to groundwater from fertiliser application was a major contributor to additional water treatment costs to Cholderton & District Water Company for nitrate removal to meet drinking water standards. However, 2021 levels showed that nitrate in water is sufficiently low and hence additional treatment is not currently required and hence cost is not incurred. This situation is assumed to continue over the accounting period.
Recreation	Welfare value based on Orval methodology (Day et al 2018)
BPS & Agri-env income	Income to the Estate based on latest farm plans. This is included as it is both a benefit to each Estate and a cost to the taxpayer (wider society) and relates to stewardship of natural assets. This is shown in the NCBS as a private income to each Estate and as a liability (cost) to the public. The system of agri-environment payments is changing, but in the absence of any details of the structure of future payment schemes the overall level of payment has been assumed constant.
Biodiversity	The units were valued at £11,000 per unit to provide a proxy for biodiversity value (Defra, 2019).
Non-natural capital income	Income provided to the landowner by non-natural capital assets, such as cottage and property lets and rents. These are not solely or significantly dependent on natural capital but are included here to show the reality of the Estate's finances.

Monetary flow estimates are shown net of financial costs of producing them – when such costs are incurred (e.g., variable production costs of harvesting or fertiliser application to the provision of arable crops). In

[3] Note these estimates are under review and new values were expected to be produced by BEIS at the end of 2020 but are yet to be updated.

order to avoid double counting of costs, business costs were allocated to one of the four categories below (Table 2.5).

Table 2.5: Treatment of Estate Costs in the Natural Capital Balance Sheet

Category	Description and treatment	NCBS section impacted
Cost of production (for natural capital benefits)	Variable cost which is deducted from the relevant benefit (e.g., harvesting cost is deducted from gross crop income)	Incorporated in the asset values to show net values
Natural Capital Maintenance Cost	Costs of activities that maintain natural capital assets, (e.g., woodland management)	Liabilities – Natural capital maintenance
Non-natural capital costs	Costs incurred in producing non-natural capital benefits (e.g., maintenance of holiday cottages)	Incorporated in the non-natural capital to show net values
Overheads	All other business costs not covered above (labour, repairs, energy, depreciation of equipment and finance costs) and that cannot be disaggregated across production and maintenance costs	Liabilities – Other Business Costs

Natural capital maintenance costs are described in Section 2.2.7.

2.2.7 *Natural Capital Maintenance Costs*

A key aim of this test project was to establish the activities and costs that maintain natural capital assets. A list of potential activities was shared with the owners (Table 2.6) to identify those that are appropriate to each estate. Methods for estimating the costs of these activities are described for each Estate in the respective sections (3 and 4).

Table 2.6: List of Potential Maintenance Activities

Maintenance Activity	Examples
Increase soil carbon sequestration	Application of manure, use of biochar, minimal tillage
Reduce compaction, surface water runoff, and increase infiltration	Subsoiling, aeration, use of cover crops
Reduce ammonia emissions to the air	Precision application of fertiliser
Actions under agri-environment schemes	Provision of wild bird seed
Hedgerow management	Hedge cutting, re-laying
Field margin management	Establishment and topping
Woodland management	Monitoring for pests/disease, thinning
Maintaining public and / or permissive rights of way	Maintain fencing and signage

2.2.8 *Natural Capital Balance Sheet*

The accounting output is a natural capital balance sheet, plus an additional element for non-natural capital assets (such as cottages for rent or commercial units). The balance sheet output is shown in

Table 2.7. All figures are 60 year present values discounted at HM Treasury discount rates to express values in 2020 terms (HM Treasury, 2020).

Normally, the account would be for a single scenario, usually the baseline position for an estate. In this project, the natural capital balance sheet was produced for both the baseline and for a future scenario which modelled the proposed Land Management Plan. The two scenarios can then be compared in the same balance sheet format.

Key features of the format:

- The rows show the value of benefits (assets) and the costs of maintaining those assets (liabilities). The assets less the liabilities provide a net value of natural capital and non-natural capital – with the caveat that, without complete read across from maintenance activities to asset values, a positive 'bottom line' cannot be interpreted as sustainable management of natural capital;
- The columns show the two scenarios for the future: continuation of baseline and a future with the proposed Land Management Plan and the difference between these two scenarios.
- Benefits that accrue to the estate owner (private) and to other businesses and the general public (public) are shown separately.

Table 2.7: Natural Capital Balance Sheet Template

	Baseline Plan		**Future Scenario with LMP**		**Difference**	
(Present value over 60 years)	Private	Public	Private	Public	Private	Public
Base year: 2020	£'000	£'000	£'000	£'000	£'000	£'000
Assets						
Benefit 1, 2, …						
Total asset value						
Liabilities						
Natural Capital Maintenance Costs						
Legal obligations						
Other maintenance						
Other Business Costs						
Overheads						
Total liabilities						
Total net asset value						
Non-natural capital:						
Benefit 1, 2, …						
Overall Economic Value						
Benefits from natural capital (non-monetised)						
Benefit 1, 2, ….						

Notes: As you will see in Sections 3.4 and 4.4 – the balance sheet is accompanied by notes on how individual cells are calculated – with more detail provided in Annex 1.

2.2.9 *Interpreting the natural capital balance sheet*

Various notes and supporting interpretation of the account are also provided as part of the accounting process. This includes:

- Key messages, which highlight the most significant features identified in the natural capital balance sheet;
- Implications for management. A list of potential actions for the Estate to consider for ongoing management of natural capital; actions for preserving value, opportunities for enhancement and risks to be manged, and
- List of exclusions, detailing those benefits and maintenance activities that may be material for the Estate, but for which sufficient information for valuation was not available and hence excluded.

2.3 Using natural capital balance sheet for Environmental Land Management scheme

An account was produced for each of two future scenarios:

- **Baseline scenario** which describes the continuation of current land use and management practice with a few committed and projected changes, and
- A **Future scenario** based on Land Management Plans (LMPs) for each Estate which includes improvements to farming practices and some land use change so that all or some of the public good benefits from natural capital could be increased or public disbenefits could be reduced - influenced by the goals of the Estate owners.

Phase 1 produced a baseline account for both Estates, which was used to inform opportunities for improvements for inclusion in the improved LMPs. The process was then be repeated to produce accounts for the future scenario as illustrated in Figure 2.3.

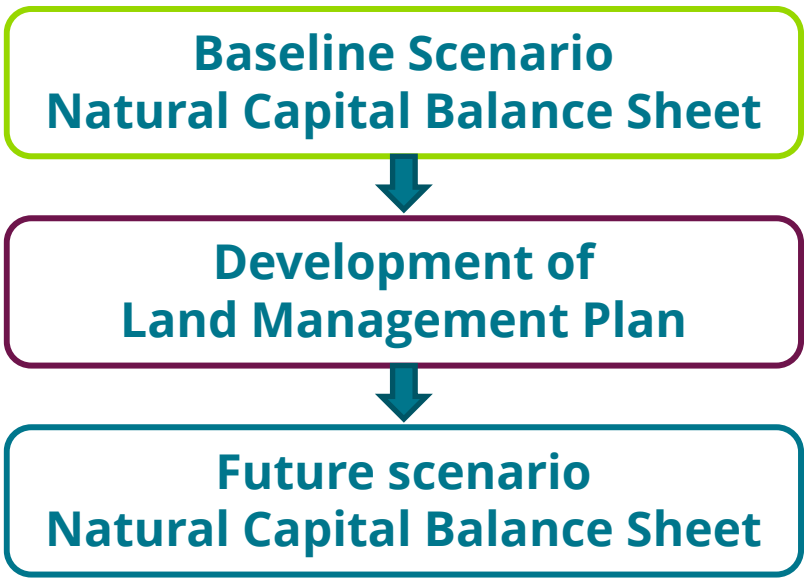

Figure 2.3: Outline of the Pilot Test Process

3. Cholderton Estate Account

This section presents the natural capital balance sheet for both the baseline and future land scenario for the Cholderton Estate. The future scenario reflects the expected changes in the benefits provided and maintenance and product costs due to the proposed Land Management Plan (LMP). The section starts with an interpretation of the balance sheet results in terms of key messages, and implications for estate management.

3.1 Key Messages

The key messages from the natural capital balance sheet analysis are:

- The baseline scenario shows that the Estate makes a return and needs income from, farming, agri-environment schemes and non-natural capital assets (such as property rental) in order to cover all business overheads and make a net profit. Significant reductions in any of these income streams could result in the business becoming lossmaking. This position improves in the future LMP scenario, with the introduction of solar farm income, and provides a degree of resilience to falls in other income streams.
- In addition to private income, the estate also generates public benefits of around £120 million over 60 years, including biodiversity, net greenhouse gas sequestration, air pollution removal and provision of public rights of way or nearly £6 million if biodiversity valuation is not included. Biodiversity is a very significant benefit at Cholderton but difficult to evaluate adequately in monetary terms. For the purposes of providing an indicative value, we have used the Defra biodiversity metric to estimate the cost of reproducing this habitat elsewhere.
- The high value estimate reflects the rich biodiversity on Cholderton Estate and the way it is managed to maintain natural capital, employing farming techniques to maximise wildlife diversity, eliminate the use of organic fertilisers, pesticides, and herbicides. This is also reflected in enhanced soil carbon and resilience to climate change.
- Carbon sequestration in soil is a major potential opportunity to deliver climate regulation benefits and to entirely offset the emissions from livestock on the farm. However, due to lack of soil data for the farm, this is subject to a high degree of uncertainty around both the rate of sequestration and the capacity of the soils to store more carbon. Given the huge potential of soils to store carbon[4] it is important that farms can measure and monitor carbon storage and sequestration overtime. We recommend that Defra support measures to enable farms to access reliable methods of soil carbon measurement and monitoring.
- GHG footprint of farming is material, the main farm system disbenefit being greenhouse gas emissions, mainly from enteric fermentation and decomposition of manure from livestock, but also from fossil fuel use. A level of emissions from livestock is unavoidable, however the Cholderton approach includes sainfoin in the grazing diet which can reduce enteric fermentation emissions by around 12%. Further methods for reducing greenhouse gas emissions should be explored.

[4] 1% increase on soil organic matter to a depth of 25cm is roughly equivalent to 50 tCO_2e sequestered in typical soil.

- Impacts of climate change (as drought) have been modelled as additional costs for bought in livestock feed but have assumed to be mitigated by 80% due to Cholderton's soil and land management approach (building soil organic matter, eliminating the use of pesticides/herbicides, the use of deep rooting grass leys that all improve soil structure and resilience to drought). Consequently, the reduction in net food income is relatively small (amounting to less than £10 k over 60 years.
- The future scenario (the Land Management Plan) includes changes for the provision of solar renewable energy generation and an enhanced level of soil carbon sequestration.
- During the project, other opportunities emerged for potential improvement, such as woodland restoration and creation and steps to reduce emission from farm operations, (see Section 3.2). The Estate could consider these as areas for further improvement.

3.2 Implications for Estate management

While the natural capital account is partial and based on available information and assumptions throughout, the process of putting the account together generates valuable lessons for Estate management. Here these lessons are summarised in terms of opportunities for improvement in estate management; risks included in the accounts; generating new finance opportunities and improvements to the accounting process.

Opportunities

On maintaining and improving the benefits to the Estate and wider society: The Estate's approach to soil management sustains soil, preserving its structure, health, productivity, and resilience. The main opportunity for enhancement consists of increasing soil carbon further and hence delivering further carbon sequestration benefits and resilience to climate change.

However, due to a limited soil sampling data, the range of potential carbon sequestration benefit is difficult to predict and can only be estimated in broad terms (assumptions produce a range of around £5 million to £10 million in present value terms over 60 years). The average annual rate of sequestration in soil would need to be around 1.5 tCO_2e per hectare to offset all farm emissions[5]. We recommend that the Cholderton Estate seek assistance in measuring existing soil organic carbon levels and seek advice on what current research/evidence suggests is a realistic rate of carbon sequestration that can be attributed to Cholderton practice.

Other opportunities for potential improvement include:

- Restoration of woods in moderate/poor condition (as identified in the woodland management report), i.e., "removal of diseased ash/re-stocking cleared areas, and introduce a regular cycle of thinning, coppicing and re-stocking will help align woods to the aspirations of the 25 YEP" (Field, 2020). This would improve carbon sequestration, timber output and potentially improve woodland biodiversity.

[5] Farm emissions from Table 3.1(1,234 tCO_2e/year) divided by 820 ha of farm soils = 1.5 tCO_2e.

- Creation of new woodland, with 8 ha being identified as a suitable opportunity (Field, 2020). This would improve carbon sequestration and possibly provide an opportunity for income from voluntary carbon credits.

We recommend that the Estate considers these opportunities and develops specific schemes for improvement and inclusion in future land management plans.

On reducing the disbenefits to wider society: The organic approach avoids or minimises many farming disbenefits such as water pollution from nitrate leaching, air pollution and greenhouse gas emissions from the use of inorganic fertilisers. The main farm system disbenefit is greenhouse gas emissions from enteric fermentation and decomposition of manure from livestock. A level of emissions from livestock is unavoidable, however the Cholderton approach includes sainfoin in the grazing diet which can reduce enteric fermentation emissions by around 12%. Further innovations to livestock diet may reduce this further and is a topic of ongoing research. The Cholderton Estate should follow developments and consider dietary changes as appropriate.

Whilst the scope for reducing livestock and manure emissions is limited, the Estate uses over 50,000 litres of diesel per year and over 70,000 kWh of grid electricity, producing a combined emissions value of 151 tCO_2e per year. Diesel use represents nearly 90% of this emissions value, and hence is a priority for measures to reduce fossil fuel use. In future, opportunities to switch to low carbon farm machinery will become more available and affordable, but in the meantime measures to reduce fuel use could be explored.

Table 3.1: Cholderton Baseline Greenhouse Gas Sequestration and Emissions (2020)

Sequestration/ Emission Source	Sequestration or (Emissions) (tCO_2e/year)	Value in 2020 (£)	60 Year Present Value (£)
Woodland	687	48,509	2,745,317
Hedgerows	207	14,634	916,300
Soil	1,333	94,085	5,153,540
Total Sequestration	**2,228**	**157,228**	**8,815,157**
Livestock	(816)	(57,575)	(3,605,081)
Manure management	(267)	(18,835)	(1,179,338)
Farm energy use	(151)	(10,685)	(669,044)
Total farm emissions	**(1,234)**	**(87,094)**	**(5,453,463)**
Net Estate GHG flow	**994**	**70,133**	**3,361,693**

Note: (brackets) denote emissions and dis-benefits.

We recommend that the Estate considers these opportunities and develops specific schemes for improvement and inclusion in future land management plans.

Risks included in the baseline

Climate change represents one of the most significant risks to agriculture, with the UK trend for more unpredictable rainfall in addition to a general trend for wetter winters and drier summers. Deep rooting grass leys which are part of the Cholderton land management approach improve soil structure and

resilience to drought. Empirical experience from Cholderton indicates that the Estate has been less impacted than neighbouring farms, avoiding the need to buy in extra forage and feed during the prolonged periods of drought (particularly in 2018).

UKCP18[6] estimates that a "hot" summer such as 2018 current has historically had an annual probability of 10%, but this will increase to 50% (depending on the global emissions scenario) by mid-century. It has not been possible to predict what this means for Cholderton Estate within the scope this account or the resilience of soils at Cholderton to such increase in drought frequency. However, it is possible to develop an assumption set based on realistic examples to illustrate the potential scale of the consequences of drought and to approximate the range of resilience benefit that is possible. Assuming even the historic probability of 2018 drought repeating 1 in every 10 years from 2030 (5 severe droughts in total over the period 2030 to 2080), loss of forage and fodder crops could amount to 25-40% of livestock requirements. For Cholderton, a requirement to purchase an additional 25-40% of livestock feed costs would be around £18-29k per drought, and over 5 droughts would amount to £90-145k in additional bought-in food costs alone (NFU, 2019). Based on experience from the 2018 drought at Cholderton, around 80% of these costs could be feasibly avoided due the condition of the Estate's soils. If such avoided cost can be achieved then an indicative value for the resilience of the soil is in the region of £72-116k over the years 2030-80, in avoided forage and feed crop losses. Clearly, if droughts become even more severe and frequent these benefits will increase accordingly until such a time that the choice of crop or other farm business will need to be reconsidered.

We recommend the Estate regularly reviews the latest forecasts of climate change projections (particularly the Climate Change Risk Assessments, the next one of which is due in June 2021) and the likely impacts on the condition of natural capital and implications for land use and management.

On generating income for the Estate:

- On the basis of the current level of BPS and agri-environment payments, this income line would equate to around £7.3 million in present value terms over 60 years. This is a substantial value and whilst intended to incentivise beneficial environmental outcomes, the current system does not provide an exact linkage between the level of payment and the level of benefits delivered. The future ELM scheme is intended to provide a better relationship between the level of payment and benefit provided, most importantly, it is expected to reward maintaining good quality. However, the details remain to be seen. The Estate delivers significant biodiversity, water quality and carbon sequestration benefits, some of which (but not all) have been evaluated in Table 3.5. Therefore, it is recommended that the Estate continues to engage with the ELM scheme development and considers applying for it.
- Emerging markets for carbon credits may provide future opportunities for funding sequestration benefits. Currently markets are voluntary yet demand for woodland carbon credits is strong as buyers like the permanency and predictability of carbon stored through woodland creation (rather than for existing woodland maintenance or soil sequestration). Markets are likely to develop further, and the Estate should regularly review the opportunities to earn income from (additional) sequestration benefits.

[6] Met Office UKCP18 probabilistic climate projections indicate upper decile (1 in ten year) summer rainfall at 31% below 1981-2000 average for scenarios RCP2.6 and RCP4.5. https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/download-data

- Diversification of income is also an important consideration for the business (such as scope to increase commercial rental income), but strays into areas that are not necessarily dependent on natural capital.

On the natural capital accounting process:

- Natural capital accounting could be a good way to communicate the environmental, financial, and public good benefits of the way Cholderton Estate is managed. This is the case even if some key elements of the benefits, or resilience to future risks, cannot be fully quantified or expressed in monetary terms. The key is to demonstrate the transferability of the lessons from the accounting and LMP process.
- The accounting process reveals the actual (or potential) key benefits and the key data gaps. For example,
  - Carbon sequestration in soil is a major potential opportunity to deliver climate regulation benefits but, due to lack of soil data for the farm, is also subject to a high degree of uncertainty around both the rate of sequestration and the capacity of the soils to store more carbon. Soil sampling and monitoring are vital if this important benefit is to be successfully managed and delivered.
  - The benefits of soil resilience are difficult to predict, but are significant, hence better forecasting and modelling approaches, at the farm level, are needed to estimate the likely benefits of maintaining current resilience (or adaptation).
  - The Estate incurs substantial overheads, and it is important to understand whether the sum of private benefits is sufficient to cover these expenses and for the estate to make an overall profit. Therefore, a more detailed monitoring of the different types of costs – in particular maintenance and production – is recommended.

3.3 The scope of the Natural Capital Account

3.3.1 *Asset register*

Natural capital of the Estate is defined in terms of the major land uses as shown in Table 3.2.

Table 3.2: Cholderton Baseline Natural Capital Quantity by Land Type

Major Land Use Type	Area (ha)	%
Arable	240	24%
Modified Grassland	200	20%
Semi-natural grassland	440	44%
Woodland - broadleaf/mixed	120	12%
Total	**1,000**	**100%**

The farm is fully organic, comprising a large area of lowland calcareous grassland (shallow soil chalk downland, which has been restored over several decades and is managed through an Environmental Stewardship agreement). A further 45% is farmed using an arable/grassland 10 year rotation – 6 years grass and herb rich leys, followed by 4 years of arable crops. This system uses deep rooting nutritious leys incorporating a high leguminous content, which improves soil formation, soil structure and helps increase

levels of soil organic matter. The mixed farmland also incorporates wide grass margins providing habitat for invertebrates and other wildlife.

In terms of soil quality, no data on soil organic carbon levels or other soil quality data were available, however, the Cranfield University report for this test pilot project (Rickson et al 2020) noted for the Chloderton Estate that, "The fertile, microbially rich, healthy soils underpin production of meat and arable crops, whilst delivering other ecosystem goods and services. These include clean water (fewer agrochemicals in surface or ground waters); clean air (no nitrous oxide or carbon dioxide emissions from inorganic fertilisers or soil exposure to the atmosphere, and no spray drift from application of herbicides or pesticides); and an outstanding range of wildflowers, grasses, insects and birds, all reliant on healthy soils."

Other salient aspects of natural capital quality include:

- Species diversity is exceptionally high and a unique feature of the Estate at Cholderton, comprising over 1,500 recorded species (many rare and declining nationally), including 70 plant species associated with arable land, 137 bird species recorded, 740 moth species, 40 butterfly species, and 7 amphibian/reptile species.
- 96km of hedgerows that are wide and thick and in good condition[7].
- Woodland above ground carbon stock (Field 2020) was estimated at 30,700 tCO_2e, or (264 tCO_2e per ha). (Field 2020) noted that most woodland was in moderate condition, but some woodland (less than one fifth) was in poor condition (i.e. diseased ash and areas requiring re-stocking). Improvements in management may produce improved tree growth for enhanced carbon capture, timber and energy production.

The land is in a Nitrate Vulnerable Zone, and there have been problems for nitrate levels in public water supply arising from high levels of nitrate leaching form farm diffuse pollution (mainly use of nitrogen based fertilisers). The Cholderton estate itself contributed around 8% of the nitrate loading (Rickson et all 2020), 5% of which was due to a leaky slurry lagoon which was remedied around 2016. This suggests that Cholderton contributes 3% or less of the total nitrate loading in the catchment, the loading being avoided through the use of organic manures rather than nitrate fertilisers.

3.3.2 *Materiality assessment*

Table 3.3 shows the materiality assessment of benefits by major natural capital asset type. Most benefits were evaluated in monetary terms, although biodiversity has been evaluated on an indicative basis only and should be interpreted with care. Other benefits that were considered potentially significant, but which were not addressed due to lack of data were: the water flow regulation benefits of land (contributing to water supply), air pollution removal for land types other than woodland, and the flood risk mitigation benefits of all land types.

[7] *Private communication A Cross: Hampshire and Ilse of Wight Wildlife Trust.*

Table 3.3: Materiality Assessment for Cholderton Estate Natural Capital Assets and Benefits for Accounting Purposes

Private & Public Benefits	Arable	Improved grassland	Semi-natural grassland	Woodland - amenity
Food production	●	●	●	
Other - Seed production	●	●	●	
Timber production				●
Water supply				
Renewable energy	●	●		
Woodland Burials				●
Climate regulation	●	●	●	●
Air quality regulation				●
Water quality	●	●	●	●
Flood risk management				
Recreation	●	●	●	●
Biodiversity	●	●	●	●
Agri-environment income	●	●	●	●

Legend:	
Material benefit	
Potentially material but not assessed due to lack of data	
No material service provision	
Benefit estimated in quantitative and/or monetary metrics	●
Benefit estimated in qualitative terms	○

3.3.3 *Baseline and Future Land Management Plan Scenarios*

The Cholderton management approach maintains soil condition and biodiversity as a main priority, so the scope for further improvement is correspondingly reduced. Hence, the natural capital account has mainly served to highlight the relative value and importance of the various natural capital benefits and the Land Management Plan focuses on maintaining those rather than proposing a major change in land management approach. However, there are two elements that have varied between the baseline and future LMP scenarios:

- Carbon sequestration in soil and,
- The proposed plans to install a solar energy farm.

Firstly, carbon sequestration in soil is a major potential opportunity to deliver climate regulation benefits but, due to limited soil data for the farm, is also subject to a high degree of uncertainty around both the rate of sequestration and the capacity of the soils to store more carbon. More soil sampling and analysis would help clarify both. Comments from the owner suggest that the application of manures and the selective use of deep rooting legumes is still enriching the soil, specifically (based on Edmunds, 2020):

- "Sainfoin and Lucerne have tap roots that penetrate the subsoil, these together with a complex network of smaller rootlets, make them very drought tolerant. It is decomposition of this complex root structure that introduces organic matter into previously depleted soils. Sainfoin develops four times as much root as Lucerne and is hence better able to withstand drought than any other forage crop".

- Rational use of regular leguminous based leys on arable soils helps to increase soil organic carbon in arable soils that would otherwise rely solely on application of manure for organic matter.

Given the limited data on existing levels of soil organic carbon at Cholderton, the following assumptions (Table 3.4) have been made for the baseline and future LMP scenarios, based on feasible rates of sequestration in soils. For full details on the discussion of assumptions see the climate regulation section of, Annex A.1.2.2 Benefits to wider society.

Table 3.4: **Soil Sequestration assumptions by land use and Scenario at Cholderton**

Land Type	Current Estimated SOM%	Baseline target (to 2070)		Improvement plan target (to 2070)	
		Target SOM%	Annual sequestration (tCO_2e/ha)	Target SOM%	Annual sequestration (tCO_2e/ha)
Rotational arable/leys (average over 10-year cycle)	10%	11%	1.82	12%	3.65
Permanent grassland	12%	13%	1.22	14%	2.43

These assumptions were applied to all farmland soils (820 ha) on the estate and provide an indication of the range of carbon sequestration benefit that may be delivered over the forecast time horizon. These assumptions produce a range of around £5 million to £10 million in present value terms over 60 years. These high values (broadly equivalent to either current food production or current BPS and agri-environment income combined) indicate the importance of investigating current soil organic carbon levels and understanding the rate of sequestration that can be attributed to the ongoing soil management practices at Cholderton. Consequently, we recommend that the Cholderton Estate seek assistance in measuring existing soil organic carbon levels and a realistic rate of carbon sequestration that can be attributed to Cholderton practice. In the longer term, Cholderton represents a valuable opportunity to monitor and quantify the soil sequestration benefits of their land management approach.

Secondly, the Cholderton Estate has agreed to the installation of a solar photovoltaic farm (50 MW capacity) on 95 ha of grassland. Installation is expected to commence soon, with the the first power being generated in early 2022. After installation, this land will still be grazed by sheep, thereby providing the dual benefits of renewable energy generation, and feeding of livestock. The value of the expected energy produced has been conservatively estimated at the minimum annual guaranteed land fee under the heads of terms agreement between the Cholderton Estate and the energy provider. This income stream is significant for the Estate (£4.8 million in present value terms) and highlights the value of activities that can generate revenue whilst retaining land in productive agricultural use.

3.4 Natural Capital Balance Sheet

Table 3.5 presents the baseline and future LMP natural capital balance sheet for Cholderton showing the monetary estimates of the asset values (private benefits to the Estate and public benefits) that are dependent on natural capital; the (legal and voluntary) liabilities for maintaining the natural capital assets and costs of producing the asset values.

Table 3.5: Cholderton Estate Natural Capital Balance Sheet and Non-natural Capital Balance Sheet

Confidence	Summary of asset values (Present value over 60 years)[1] Base year: 2020	Baseline Plan Private £'000	Baseline Plan Public £'000	Future LMP Private £'000	Future LMP Public £'000	Difference Private £'000	Difference Public £'000
	Assets						
●	Food production [2]	5,400		5,400		-	-
●	Other - Seed production [3]	300		300		-	-
●	Timber production & grants [4]	100		100		-	-
●	Renewable energy [5]	-		4,800		4,800	-
●	Woodland burials [6]	600		600		-	-
	Climate regulation impacts: [7]					-	-
●	C sequestration woods/hedges [7a]		3,700		3,700	-	-
●	C sequestration in soil [7a]		5,200		10,300	-	5,100
●	Farming GHG emissions [7b]		(5,500)		(5,500)	-	-
●	Air quality benefits [8]		800		800	-	-
●	Water quality benefits [9]		500		500	-	
●	Recreation [10]		1,200		1,200	-	-
●	BPS & Agri-env income [11]	7,300		7,300		-	-
	Total gross asset value	**13,700**	**5,600**	**18,500**	**11,000**	**4,800**	**5,100**
●	Biodiversity [12]		> 115,300		> 115,300		
	Indicative asset value	**13,700**	**> 121,200**	**18,500**	**> 126,300**	**4,800**	**5,100**
	Liabilities						
	Natural Capital Maintenance Costs						
●	Legal obligations [13]	(700)		(700)		-	-
●	Other maintenance		(7,300)		(7,300)	-	-
	Other Business Costs						
●	Overheads [14]	(11,700)		(11,700)		-	-
	Total liabilities	(12,400)	(7,300)	(11,400)	(7,300)	-	-
	Total net asset value	**1,300**	**> 113,900**	**6,100**	**> 119,000**	**4,800**	**5,100**
	Non-natural capital: [15]						
●	Property & wayleave	800	-	800	-	-	-
	Overall Economic Value	**2,100**	**> 113,900**	**6,900**	**> 119,000**	**4,800**	**5,100**
	Benefits from natural capital (non-monetised)						
●	Insect species abundance	18 bee species 40 butterflies 740 moths		18 bee species 40 butterflies 740 moths		Sustained (No Change)	
●	Wild bird species	137 species		137 species		No Change	
●	Number of wild flowers	+70		+70		No Change	

Table notes: Confidence ratings for benefit and cost estimates are rated as high (green), medium (amber), low (red), see Annex 1.2 for definitions. It has not been confirmed that the level of maintenance costs is sufficient to sustain the benefit levels in the account.

1. Present value calculated over 60 years, 3.5% discount rate declining to 3% after 30 years in accordance with HM Treasury Green Book (2020).
2. **Food production:** Income and production costs are based on the farm plan for 2020/21 and assumed to continue into the future. This assumption requires that, as a minimum, the current soil condition is maintained. **Assumed impacts of climate change have been modelled as an increase in production costs rather than a fall in output**.
3. **Other** output relates to the production and sale of seed (Yellow Rattle) and based on current income from 2020/21 farm plan.
4. **Timber production & grants:** Timber output is small and has been assumed to have negligible value based on low harvest output. Value of woodland grants is based on 2020/21 farm plan and assumed to continue at the same level throughout the accounting period.
5. **Renewable energy:** No generation in the baseline plan, but there are plans to install a solar farm (50 MW output) forecast to generate power from 2022. Income assumed at the guaranteed minimum income per acre based on agreed Heads of Terms with the energy provider. Land for the site will still be used to graze sheep.
6. **Woodland burials:** Based on estimated income from 2020/21 farm plan and assumed to continue throughout the accounting period. There is no change between baseline and future LMP scenarios.
7. **Climate regulation**: **(a) Carbon sequestration:** Sequestration in woodland is assumed at the average UK rate (5.7 tCO_2e per ha per year[i]. Soil sequestration in grassland and rotational soil has been based on an assumed steady increase in soil organic matter % over a 50-year period, to 2070 and remain carbon neutral for the last 10 years of the accounting period (2070-2080) (1% for baseline, 2% for the LMP). Soil in woodland has been assumed to be close to carbon saturation, hence soil sequestration has been set at nil for woodland. **(b) Farm GHG emissions:** Estimates for livestock emissions are based on UK average enteric fermentation emissions but allow for a 12% reduction due to the beneficial impacts of sainfoin on livestock diet[ii]. Emissions from decomposition of manure, electricity and diesel use are based on UK average assumptions. All flows are valued using central non-traded carbon values[iii] which escalate by year (from £72/tonne in 2020) to reflect the increasing value of carbon abatement overtime.
8. **Air quality:** Quantity of fine particulate air pollution (PM2.5) removal by woodland cover for the local authority in which the woodland lies (Test Valley); valued at the avoided medical expenditure based on England average[iv].
9. **Water quality benefits**: Organic farming and use of nitrogen fixing legumes provide support to water quality in the catchment. Indicative wider water benefit is based on National Water Environment Benefit Survey (NWEBS)[v] values for the River Bourne water body, allocating a value for avoiding deterioration to existing WFD condition (moderate) at £827k in 2012, rebased to £953k in 2020. Value attributed to Cholderton (£20.3k) is based on the proportion of the water body (c 1km) that flows through the Estate, compared to the total river length (47km). Nitrate leaching disbenefits are assumed negligible due to the planting of legumes and avoiding the application of nitrate fertiliser altogether.
10. **Recreation**: number and welfare value of recreational visits through public footpaths on Estate using the ORVal tool[vi]. Value varies by location and assumes average condition of natural environment. The value does not include the health benefits of active exercise in nature.
11. **BPS and Agri-environment income:** is shown as a private income to the Estate and as a cost to the wider public (taxpayer). Values are based on figures from the 2020/21 farm plan and assumed to continue at the same level over the accounting period. Future ELM payments are impossible to forecast and including them may risk doublecounting with benefits included elsewhere in the balance sheet.
12. **Biodiversity:** A proxy for value is used combining the Defra Biodiversity metric units[vii] and a representative cost per unit. This does not capture the specific biodiversity features of Cholderton but provides an indication of the cost of reproducing this habitat elsewhere if funded through a biodiversity credit scheme. Biodiversity units were assessed as a high level desktop analysis of the current Cholderton land type and condition. The biodiversity units attributed to Cholderton were the difference between the units for the current state and a counterfactual case of intensive agricultural production. The units were valued at £11,000 per unit as an assumed value in Defra (2019)[viii].
13. **Agri-environment obligations:** have been estimated from current higher stewardship schemes, making an allowance (based on farm accounts) for seed and use of farm labour.
14. **Overheads:** These costs are from the farm business plan and include all costs not included elsewhere (e.g. for natural capital maintenance or variable costs of production) including labour, repairs, energy, an allocation of overheads and depreciation of farm equipment.

15. **Non-natural capital** income is based on farm financial plans and includes rents on properties and wayleave. Expenses that correspond to this income line include rental property expenses and an allocation of overheads.

The table also shows benefits that are not dependent on natural capital but make a contribution to the financial sustainability of the estate.

Benefits that we could not fully quantify in monetary terms:

Biodiversity is a very significant benefit at Cholderton but difficult to evaluate adequately in monetary terms. The diversity of species at Cholderton is unique: "The range of species recorded on Cholderton is quite remarkable. Mr Edmunds has records of 1500 species including many rare and declining ones, which have been verified by the various conservation bodies" (Cross, 2020). The variety of plant and animal species is a key feature of the Estate and it is this uniqueness that presents particular challenge to valuation. For the purposes of providing an indication of value, the Defra biodiversity metric has been used to estimate the cost of reproducing this habitat elsewhere – as mentioned in note 12 to Table 3.4. However, this would still fall short of capturing the benefit of the variety of species found at Cholderton. As such this biodiversity metric valuation should be considered a de minimis value for the biodiversity of the Estate of at least £100 million in public benefit, which, when compared to other benefits, is a fair reflection of the *relative* benefits of the Estate.

Exclusions:

- **Water quantity** – soils and woodland play an important role in regulating the flow of water and can contribute towards mitigating flood risks and sustaining water supply in periods of drought. This is a potentially significant benefit in the baseline or the future LMP but, to be properly evaluated, requires hydrological modelling of the catchment, which is beyond the scope of this account.

4.Snoddington Manor Estate Account

This section presents the natural capital balance sheet for both the baseline and future scenario for the Snoddington Manor Estate. The future scenario reflects the expected changes in the benefits provided and maintenance and production costs due to the proposed Land Management Plan (LMP). The section starts with an interpretation of the balance sheet results in terms of key messages, and implications for estate management.

Caveat: Figures used in this account have been taken from the proposed Snoddington Farm Management plan, but there has been very little dialogue with the owner of Snoddington Manor Estate to test and confirm that assumptions have been selected and interpreted on a reasonable basis. The account should be read with an appropriate degree of caution.

4.1 Key Messages

The key messages from the natural capital balance sheet analysis are:

- The balance sheet baseline scenario shows that the Estate makes a return from farming, solar energy generation, BPS and non-natural capital assets (through rents). The analysis suggests that BPS income is a smaller proportion of total income (compared to Cholderton) and the business could possibly avoid becoming lossmaking if this were removed. From the farm business plan, it is not clear if the Estate receives any agri-environment payments, and none have been assumed.
- In addition to private income, the estate also generates some public benefits of £3.5 million over 60 years including carbon sequestration and air pollution removal benefits of woodland, recreational value of public rights of way, and some biodiversity value (grass margins, hedgerows, wildflower margins around the solar park, creation of a chalk down meadow).
- These benefits are partly offset by greenhouse gas emissions from farming (mainly fertiliser use, but also energy use). In addition, there may be other disbenefits from fertiliser, herbicide and fungicide use but these are difficult to evaluate without further information.
- The future scenario (the Land Management Plan) assumes a 30% reduction in fertiliser use and a change in the rotational crop plan. The modelled dis-benefits of greenhouse gas emissions through lower fertiliser use reduce correspondingly. The impact on farm yields is a small reduction which is more than offset by a significant reduction in farm overhead costs through lower use of energy and machinery. Overall, both private income and public benefits increase.
- The major risk for the Estate is uncertainty around the sustainability of arable soils. The risk is that the cropping plan and use of inputs do not sustain soil structure, organic carbon levels, and resilience to future pressures such as climate change. To reflect this risk, if crop yields fall by 1% year on year from 2030, the impact on food benefit being around £1.6 million reduction over the period to 2080.
- Conversely, soil provides a significant opportunity to increase carbon storage. No data on soil carbon was available, hence no values for soil sequestration have been included in the balance sheet. There are over 500 ha of farmed soils on the Estate and 1% increase in soil organic carbon can sequester around 50-60 tCO_2e per hectare.

4.2 Implications for Estate management

While the natural capital account is partial and based on available information and assumptions throughout, the process of putting the account together generates valuable lessons for Estate management. Here these lessons are summarised in terms of opportunities for improvement in estate management; risks included in the accounts; generating new finance opportunities and improvements to the accounting process.

Opportunities

On maintaining and improving the benefits to the Estate and wider society: Carbon sequestration in soil is a major potential opportunity to deliver climate regulation benefits. No data on soil carbon was available for the Snoddington Estate (other than a single soil sample which indicated SOM% at 4.7%) , hence no values for soil sequestration have been included in the balance sheet. Given the significant potential we recommend that the Estate seek assistance in measuring existing soil organic carbon levels and seek advice on what current research/evidence suggests is a realistic rate of carbon sequestration that can be achieved.

Other opportunities for potential improvement include:

- Restoration of woods in poor condition i.e., "removal of diseased ash/re-stocking cleared areas, and introduce a regular cycle of thinning, coppicing and re-stocking will help align woods to the aspirations of the 25 YEP" (Field, 2020). This would improve carbon sequestration, timber output and potentially improve woodland biodiversity.
- Creation of new woodland, with 15 ha being identified as a suitable opportunity (Field, 2020). This would improve carbon sequestration and possibly provide an opportunity for income from voluntary carbon credits.

We recommend that the Estate considers these opportunities and develops specific schemes for improvement and inclusion in future land management plans.

On reducing the disbenefits to wider society: The major quantified disbenefits from the Estate arise from the use of inorganic fertiliser, resulting in leaching to the water environment – with potential impact on public water supply, and greenhouse gas emissions (mainly nitrous oxide). Unquantified impacts include greenhouse gas emissions from decomposition of manures (application rates not known), and wider environmental impacts of herbicide and pesticide use (including impacts on soil condition and wildlife). Baseline farm emissions as estimated are presented in Table 4.1.

The most significant scope for emissions reduction is to reduce or eliminate the use of inorganic fertiliser and use lower greenhouse gas fertilisers. A 30% reduction in fertiliser use has been factored into the future LMP scenario, but the potential to go further should be explored. We recommend that the Estate explore options for making further reductions in greenhouse gas emissions from fertiliser use. This could include avoiding fertiliser use in the first instance (e.g., through regenerative or organic farming, or the greater use of fertility building crops) and if fertiliser is used, using less, using it more efficiently and using lower impact fertilisers (e.g., avoiding urea and utilising manure if it is available).

The Estate also uses around 45,000 litres of diesel and 40,000 kWh of grid electricity. The future LMP scenario implies a reduction of 6,300 litres in diesel use through less intensive cultivation. The Estate could explore options to reduce fossil use further.

Table 4.1: Snoddington Baseline Carbon Sequestration and Greenhouse Gas Emissions from Farm Operations (2020)

Sequestration/ Emission Source	Sequestration / (Emissions) (tCO_2e/year)	Value in 2020 (£)	60 Year Present Value (£)
Woodland	292	20,921	1,309,987
Soil	-	-	-
Total Sequestration	**292**	20,921	1,309,987
Fertiliser use	(373)	(26,295)	(1,646,478)
Manure management	Not known	-	-
Farm energy use	(129)	(9,122)	(571,202)
Total farm emissions	**(502)**	**(35,417)**	**(2,217,679)**
Net Estate GHG flow	**(210)**	**(14,496)**	**(907,692)**

Note: (brackets) denote emissions and dis-benefits.

Risks included in the baseline

One risk associated with intensive arable farming is that soils may gradually deplete with the consequence of falling crop yields and/or a need to spend more on higher levels of inputs (fertilisers). Depleted soils are also more likely to have lower resilience to as climate change. It is generally difficult, and outside the scope of this account, to predict future soil condition and any likely fall in crop yield. However, as an example assuming a 1% year on year reduction in yield from 2030 would reduce food production benefits by at least £1.6 million in present value terms over the forecast period and represents an 18% reduction of income over 60 years. While it is not possible to predict the scale of such a loss without more data, this is a very real risk for Snoddington, and should be explored in greater depth.

We recommend the Estate implements a 'soil protocol' that can provide a broad picture that the Estate can use to assess current soil health and quantify the effect of any changes over time. It could include soil biology (e.g., organic matter and earthworm count), physical characteristics (e.g., structure and texture), chemistry (e.g., pH, macro-nutrients and micro-nutrients) and water permeability. The aim should be to understand the factors that underpin soil condition and productivity in the long term.

UKCP18[8] estimates that a "hot" summer such as 2018 current has historically had an annual probability of 10%, but this will increase to 50% (depending on the emissions scenario) by mid-century. It has not been possible to predict what this means for Snoddington Estate within the scope this account or the resilience of soils at Snoddington to such increase in drought frequency. However, it is possible to develop an assumption set based on realistic examples and assumptions to illustrate the potential scale of the consequences of drought and to approximate the range of resilience benefit that is possible. Assuming even the historic probability of 2018 drought repeating 1 in 10 years from 2030 (5 severe droughts in total

[8] Met Office UKCP18 probabilistic climate projections indicate upper decile (1 in ten year) summer rainfall at 31% below 1981-2000 average for scenarios RCP2.6 and RCP4.5. https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/download-data

over the period 2030 to 2080[9]), crop yields can fall by 2-10% based on crop type (using the 2018 drought data) (NFU, 2019). Individual farms may experience larger reductions and future droughts may be more severe. Assuming a 10% reduction in yield per drought, would lead to a £550k loss over fifty years 2030-80). As for all farms, climate change risks are of major concern, and Snoddington Manor Estate should consider appropriate measures to build soil resilience to these future pressures.

On generating income for the Estate:

- On the basis of the current level of BPS, this income line would equate to around £2.7 million in present value terms over 60 years. The future ELM scheme is intended to provide a better relationship between the level of payment and benefit provided, and for Snoddington payments may be focused on improving margins for wildlife and eliminating adverse impacts of farm operations.
- Emerging markets for carbon credits may provide future opportunities for funding sequestration benefits. Currently markets are voluntary yet demand for woodland carbon credits is strong as buyers like the permanency and predictability of carbon stored through woodland creation (rather than for existing woodland maintenance or soil sequestration). Markets are likely to develop and Snoddington has some capacity for new woodland creation and should consider schemes which may enhance income from (additional) carbon sequestration.

On the natural capital accounting process:

- Natural capital accounting could be a good way to prioritise potential improvements which will generate public benefit and save financial costs and others for which the Estate would require financial support. This is the case even if some of key elements of the benefits, or resilience to future risks, cannot be fully quantified or expressed in monetary terms. The key is to demonstrate the transferability of the lessons from the accounting and LMP process.
- The accounting process reveals the actual (or potential) key benefits and the key data gaps. For example,
    - Carbon sequestration in soil is a major potential opportunity to deliver climate regulation benefits but, due to lack of soil data for the farm, is also subject to a high degree of uncertainty around both the rate of sequestration and the capacity of the soils to store more carbon. Soil sampling and monitoring are vital if this important benefit is to be successfully managed and delivered.
    - The benefits of soil resilience are also highly uncertain but has significant impacts on benefit levels, hence better forecasting and modelling approaches, at the farm level, are needed to estimate the likely benefits of investing in resilience (or adaptation).
    - Understanding the relationship between existing farm plans and consequences for long term soil resilience is critical both for sustained cop yields and resilience to climate change risks.
- The Estate incurs substantial overheads, and it is important to understand the impact of different types of costs – in particular how maintenance and production activities impact upon natural assets.

[9] Met Office UKCP18 probabilistic climate projections indicate upper decile (1 in ten year) summer rainfall at 31% below 1981-2000 average for scenarios RCP2.6 and RCP4.5.

4.3 The scope of the Natural Capital Account

4.3.1 *Asset Register*

Natural capital of the Estate is defined in terms of the major land uses as shown in Table 4.2.

Table 4.2: Snoddington Manor Baseline Natural Capital Quantity by Land Type

Major Land Use Type	Area (ha)	%
Arable	474	79%
Semi-natural grassland	8	1%
Woodland - broadleaf/mixed	51	9%
Margins	41	7%
Other (solar & sealed)	25	4%
Total	**599**	**100%**

The farm is 79% arable with smaller areas of woodland, semi-natural grassland and field margins. 25 ha of land has been used for a solar farm. The soil is agricultural grade 3 - Andover soil light loam over chalk. No data on soil organic carbon levels was provided.

Information on natural capital asset quality was limited but the following indicators were obtained:

- Hedgerow planting, 8 ha of downland creation, wildflower areas, field margins, pollen/nectar and bird plots provide some wildlife habitat across the Estate, but this is limited. Some hedgerows have been re-established (length not available), some are in good condition whilst others could be improved[10].
- Woodland above ground carbon stock (Field 2020) was estimated at 7,400 tCO_2e, or (180 tCO_2e per ha). (Field 2020) noted that whilst some woodland was in good or moderate condition, almost half the woodland area was in poor condition (i.e. diseased ash and areas requiring re-stocking). Improvements in management may produce improved tree growth for enhanced carbon capture, timber and energy production.

The land is in a Nitrate Vulnerable Zone, and there have been problems for nitrate levels in public water supply arising from high levels of nitrate leaching form farm diffuse pollution (mainly use of nitrogen based fertilisers). A high proportion of this loading was attributed to nitrogenous fertiliser use at Snoddington, however, by early 2021, steps to reduce diffuse pollution have reduced concentrations and there is currently no requirement for nitrate removal.

4.3.2 *Materiality Assessment*

Table 4.3 shows the materiality assessment of benefits by major natural capital asset type. Most benefits were evaluated in monetary terms, although biodiversity has been evaluated on an indicative basis only and should be interpreted with care. Other benefits that were considered potentially significant, but which were not addressed due to lack of data were: the water flow regulation benefits of land (contributing to water supply), climate regulation (i.e. carbon sequestration) from arable and grassland soils, air pollution removal for land types other than woodland, and the flood risk mitigation benefits of all land types.

[10] *Private communication A Cross: Hampshire and Ilse of Wight Wildlife Trust.*

Table 4.3: Materiality Assessment for Snoddington Estate Natural Capital Assets and Benefits for Accounting Purposes

Private & Public Benefits	Arable	Improved grassland	Semi-natural grassland	Woodland - amenity
Food production	●			
Timber production				●
Water supply				
Renewable energy			●	
Climate regulation				●
Air quality regulation				●
Water quality	●	●	●	
Flood risk management				
Recreation	●	●	●	●
Biodiversity	●	●	●	●
Agri-environment income	●	●	●	

Legend:	
Material benefit	
Not assessed due to lack of data	
No material service provision	
Benefit estimated in quantitative and/or monetary metrics	●
Benefit estimated in qualitative terms	○

4.3.1 *Baseline and Future Land Management Plan Scenarios*

The baseline scenario is based on current practice and defined by scenario A in, "Current Farming System with diversified income and BPS" from the Snoddington Farm Management Plan (BCM 2020). This provided most data for farm output, income and expenditure needed to complete the financial elements of the account.

The future scenario, referred to here as the Land Management Plan, is based on scenario E - "Farming with ELMS subsidy" from the Snoddington Farm Management Plan (BCM 2020). This scenario assumes the following differences to the baseline plan:

- A different crop rotation and
- Use of 30% less fertiliser, resulting in savings in greenhouse gas emissions and lower nitrate leaching costs.

These changes slightly reduce arable output and income (by around 3%) but produce significant savings in production costs due to less ploughing and the need for farm machinery (by around 30%).

Due to lack of engagement on soil sequestration potential, we did not assume any rate of carbon sequestration in soil or any increase due to the LMP.

4.4 Natural Capital Balance Sheet

Table 4.4 presents the baseline and future LMP natural capital balance sheet for Snoddington showing the monetary estimates of the asset values (private benefits to the Estate and public benefits) that are dependent on natural capital; the (legal and voluntary) liabilities for maintaining the natural capital assets and costs of producing the asset values. The table also shows benefits that are not dependent on natural capital but are important for the financial sustainability of the estate. The numbers in the table correspond to the notes following it. Benefits that have not been included in the monetary estimates are shown after the notes.

Table 4.4: Snoddington Manor Natural Capital Balance Sheet and Non-natural Capital Balance Sheet

Confidence	Summary of asset values	Baseline Plan		Future LMP		Difference	
	(Present value over 60 years)[1] Base year: 2020	Private £'000	Public £'000	Private £'000	Public £'000	Private £'000	Public £'000
	Assets						
●	Food production [2]	8,800		8,500		(300)	-
●	Timber production & grants [3]					-	-
●	Renewable energy [4]	1,600		1,600		-	-
	Climate regulation impacts: [5]					-	-
●	Carbon sequestration [5a]		1,300		1,300	-	-
●	GHG emissions [5b]		(2,200)		(1,600)	-	600
●	Air quality benefits [6]		300		300	-	-
●	Water quality [7]		-		-	-	-
●	Recreation [8]		1,500		1,500	-	-
●	BPS income [9]	2,700		2,700		-	-
	Total gross asset value	**13,100**	**900**	**12,800**	**1,500**	**(300)**	**600**
●	Biodiversity [10]		2,600		2,600	-	-
	Indicative asset value	**13,100**	**3,500**	**12,800**	**4,100**	**(300)**	**600**
	Liabilities						
	Natural Capital Maintenance Costs						
	Legal obligations [11]						
●	Other maintenance	(100)	(2,700)	(100)	(2,700)	-	-
	Other Business Costs						
●	Overheads [12]	(10,200)		(7,100)		3,100	-
	Total liabilities	**(10,300)**	**(2,700)**	**(7,200)**	**(2,700)**	**3,100**	
	Total net natural asset value	**2,800**	**800**	**5,600**	**1,400**	**2,800**	**600**
	Non-natural capital: [13]						
●	Property & wayleave	200		200			
	Overall Economic Value	**3,000**	**800**	**5,800**	**1,400**	**2,800**	**600**

Table notes: It has not been confirmed that the level of maintenance costs is sufficient to sustain the benefit levels in the account. Confidence ratings for benefit and cost estimates are rated as high (green), medium (amber), low (red), see Annex 1.2 for definitions.

1. Present value calculated over 60 years, 3.5% discount rate declining to 3% after 30 years in accordance with HM Treasury Green Book (2020).
2. **Food production:** Income and production costs are based on farm plans[i]. Two risks have been factored into future food production and have reduced output accordingly. Firstly, the risk that soils will deplete over time and this has been modelled as a 1% year on year reduction in yields from 2030 to 2080. Secondly, reduction in output from drought has been modelled on an assumed rate of one drought in every ten years with an average yield reduction of 6% (range 2-10%). It is assumed that the Snoddington soil condition provides no resilience to these impacts.

There is an assumed crop rotation change for the future LMP scenario which results in largely the same income but significant savings on overheads (see 12 below).

3. **Timber production & grants:** are negligible and hence not included in the account**.**
4. **Renewable energy:** income is based on farm budget for 2021 for the installed a solar farm.
5. **Climate regulation: (a) Carbon sequestration**: Sequestration in woodland is assumed at the average UK rate (5.7 tCO_2e per ha per year[ii]). In the absence of any information on steps to actively sequester carbon in arable soils, soil sequestration has been assumed as nil. **(b) Farm GHG emissions:** Estimates for nitrogen based fertiliser emissions are based on unit emission values from the model Agrecalc[iii], using application rates for fertiliser where known, and using average application rates from John Nix Farm Pocketbook[iv] where not provided. Emissions from electricity and diesel use were estimated based on farm budget energy spend and based on UK reporting emission factors[v] for diesel and electricity use. All flows are valued using central non-traded carbon values[vi] which escalate by year (from £72/tonne in 2020) to reflect the increasing value of carbon abatement overtime.
6. **Air quality** Quantity of fine particulate air pollution (PM2.5) removal by woodland cover for the local authority in which the woodland lies (Test Valley); valued at the avoided medical expenditure based on England average[vii].
7. **Water quality**: The use of artificial fertilisers, fungicides and pesticides at Snoddington presents potential disbenefits to water quality, even though they are not possible to quantify within the scope of this account. There have been historic problems of nitrate leaching threatening to breach drinking water standards due to the application of nitrate fertiliser on local farms. An EA Safeguard Zone Characterisation Report[11] identified Snoddington Manor as a major contributor to the problem. Additional water treatment costs were incurred by the Cholderton and District Water Company to lease and operate nitrate removal equipment. It is believed that taking the more sensitive fields out of cultivation at Snoddington (now used as a solar farm) has improved the situation and from 2021, there is no longer a requirement to operate the nitrate removal plant to meet drinking water standards. Given the uncertainty around future water quality impacts, no estimate has been included in this account of water benefit or disbenefit from farm operations at Snoddington, however risks should be constantly reviewed and assessed.
8. **Recreation:** The number and welfare value of recreational visits through public footpaths on Estate using the ORVal tool[viii]. Value varies by location and assumes average condition of natural environment. The value does not include the health benefits of active exercise in nature.
9. **BPS income:** is shown as a private income to the Estate and as a cost to the wider public (taxpayer). Values are from the 2020/21 farm plans based on current payment rates and assumed to continue at the same level over the accounting period. There were no figures provided for agri-environment schemes which are assessed as nil. Future ELM payments are impossible to forecast and including them may risk doublecounting with benefits included elsewhere in the balance sheet.
10. **Biodiversity:** A proxy for value is used combining the Defra Biodiversity metric units[ix] and a representative cost per unit. Biodiversity units were assessed as a high level desktop analysis of the current Estate land type and condition. The biodiversity units attributed to Snoddington where the difference between the units for the current state and a counterfactual case of intensive agricultural production. The units were valued at £11,000 per unit as an assumed value in Defra (2019)[x].
11. **Natural Capital Maintenance costs** – legal obligations were assumed to include current higher stewardship schemes however no details of these were available and hence no cost included. Other maintenance costs included the farm budget (2020/21) expenses for woodland management and assumed to be constant throughout the forecast period.
12. **Overheads** These costs are from the farm accounts and include all costs not included elsewhere (e.g. for natural capital maintenance or variable costs of production) including labour, repairs, energy, depreciation of equipment and finance costs. In the future LMP scenario, the adoption of a new crop rotation regime enables significant overhead reduction through the requirement for less farm machinery and energy use.
13. **Non-natural capital** income includes rents on cottages and wayleave. Expenses that correspond to this income include rental property expenses from the estate accounts.

Benefits that we could not fully quantify in monetary terms:

A proxy for biodiversity value based on Defra Biodiversity metric units valued at a representative cost per unit. This does not capture the specific biodiversity features of Snoddington but provides an indication of the cost of reproducing this habitat elsewhere if funded through a biodiversity credit scheme.

Exclusions:

[11] *Private communication from Trustee of Cholderton and District Water Company.*

- **Water quality** - impact of herbicide and fungicide use, due to a lack of a methodology to adequately evaluate the impacts of use.
- **Water quantity** – soils and woodland play an important role in regulating the flow of water and can contribute towards mitigating flood risks and sustaining water supply in periods of drought. This is a potentially significant benefit in the baseline or the future LMP but, to be properly evaluated, requires hydrological modelling of the catchment, which is beyond the scope of this account.

5. Lessons Learned and Recommendations

This section describes the lessons learned during this test & trial project, and summarises the relevant recommendations made earlier in this report.

Lessons learned - through the process of natural capital accounting for setting priorities:

The process of producing a natural capital balance sheet is useful in:

- Explicitly identifying the benefits of natural capital for the farm business and the wider society;
- Distinguishing material assets and benefits to focus further effort on – even if what is material has not been possible to quantify or express in monetary terms;
- Categorising costs as production and (natural capital) maintenance costs to instil a discipline of thinking and measuring 'natural capital maintenance' as a separate activity;
- Prioritising data collection and analysis tasks

The understanding of the relative value of natural capital benefits, and to whom they accrue contributes to designing Land Management Plans (LMP). Creating different balance sheets for different scenarios (baseline and options for LMPs) helps trade off different benefits (including cost savings due to LMP) and benefits against additional costs of LMP.

The accounts can help identify which are priority actions for public money (and in future blended public and private money) and which can be financed by the Estate owner. Some land management changes improve private income as well as improving natural capital (e.g., use of less fertiliser at Snoddington). In these cases the owner has sufficient incentive and ability to make the appropriate land management change. It is interesting to note that these changes may not have been contemplated without the drive to consider natural capital impacts or without the process of preparing the natural capital accounts.

Finally, the natural capital balance sheet can be used as a monitoring and evaluation tool, tracking the changes in the quality and quantity of natural capital assets and types of levels of benefits provided against by the LMP against the baseline.

Lessons learned – for practicalities of preparing natural capital accounts:

The preparation of natural capital accounts needs to be carefully planned to fit the requirements and working practices of each farmer. For example,

- Many farmers will send information in a format that is convenient for them (e.g., previous reports, other writers notes, etc.) and some will not work with Microsoft Excel™ which is used for the calculations that make up the accounts. Time to manually enter the data from the farmers to the accounts needs to be budgeted for;
- At busy times in the farming calendar, it can be difficult for farmers to respond to requests;
- Some farmers will only listen to views from trusted advisors, especially if these view run counter to firmly held beliefs;

- Face-to-face contact is likely to lead to greater exchange of ideas and openness. More accurate values and assumptions could be agreed if more in depth dialogue was held with the respective estate owners. The COVID-19 restrictions have meant that e-mail has been the main means of communication and much has been lost through this channel, and
- The more engaged the land manager is the more realistic the results and the higher the likelihood of success to delivery. This will come when ELM becomes more of a reality.

Recommendations – for the Cholderton Estate

- Seeks assistance in measuring existing soil organic carbon levels and seek advice on what current evidence suggests is a realistic rate of carbon sequestration that can be attributed to Cholderton practice;
- Regularly reviews the latest forecasts of climate change projections and understands what these mean for their practise;
- Follows developments in dietary approaches to the reduction of enteric fermentation emissions from livestock, and considers dietary changes where appropriate and feasible;
- Considers other opportunities identified in the course of this test pilot project, (for woodland restoration/creation and reductions to fossil fuel use in farm operations) and develops specific schemes for improvement and inclusion in future LMPs, and
- Explore the opportunities through emerging markets for carbon credits; biodiversity net gain and others that may develop in addition or instead of public money.

Recommendations – for the Snoddington Manor Estate

- Seeks assistance in measuring existing soil organic carbon levels and seek advice on what current evidence suggests is a realistic rate of carbon sequestration that can be achieved;
- Implements a 'soil protocol' that can be used to assess current soil health and quantify the effect of any changes over time. Such a protocol could include soil biology (e.g., organic matter and earthworm count), physical characteristics (e.g., structure and texture), chemistry (e.g., pH, macro-nutrients and micro-nutrients) and water permeability. The aim should be to understand the factors that underpin soil condition and productivity in the long term;
- Regularly reviews the latest forecasts of climate change projections and understands what these mean for their practise;
- Explores options for making further reductions in greenhouse gas emissions from fertiliser use. This could include avoiding fertiliser use in the first instance (e.g., through regenerative or organic farming, or the greater use of fertility building crops) and if fertiliser is used, using less, using it more efficiently and using lower impact fertilisers (e.g., avoiding urea and utilising manure if it is available). The latter group of actions could also lead to financial cost savings for the Estate;
- Explore the options to reduce fossil fuel use. Currently the Estate uses around 45,000 litres of diesel and 40,000 kWh of grid electricity. The LMP scenario shows a reduction of 6,300 litres in diesel use through less intensive cultivation. The Estate could explore options to reduce fossil use further

- Considers other opportunities identified in the course of this test pilot project, (for woodland restoration/creation and reductions to fossil fuel use in farm operations) and develops specific schemes for improvement and inclusion in future LMPs, and
- Explore the opportunities through emerging markets for carbon credits and biodiversity net gain and others that may develop in addition or instead of public money for funding sequestration benefits. Snoddington has some capacity for new woodland creation and should consider schemes which may enhance income from carbon sequestration.

Recommendations for the Defra ELM Test & Trial Programme

The test shows that the proposed accounting process works, namely, we can:

- Produce a baseline natural capital balance sheet to highlight the current extent and condition of natural capital assets and their various benefits;
- Use this information to inform decisions on proposed Land Management Plans, and
- Show the impact of the plans on future natural capital benefits and liabilities by producing a natural capital balance sheet showing the changes.

Therefore, we conclude that natural capital accounting can be used as a monitoring and evaluation tool, tracking the latest performance of natural capital condition and benefits against the proposed LMP.

The process makes it is possible to identify which LMP actions the Estate owner can do with no or little added cost, and for which they will need public money (or, in future, blended public and private finance). In fact, in the case of the Snoddington Estate, the LMP could include actions that will deliver both financial benefits (cost savings) and environmental improvements.

More engagement from the land manager helps create an account that is better at reflecting the current situation and future plans, and plans that have buy-in and hence higher likelihood of success to delivery. More engagement will come when ELM becomes more of a reality.

Therefore, we recommend that Defra -

- Supports the process of natural capital accounting to show the current baseline and possible improvements for which public money is sought, both at the beginning of the application process and throughout as a monitoring and evaluation tool;
- Improves knowledge and capacity of farmers to access reliable methods of soil carbon measurement and monitoring;
- Requires better recording and monitoring of production and natural capital maintenance costs, and
- Enables incorporation of climate change risks into LMP by providing easier interpretation of climate change projections for natural capital assets and land use and management at the farm level. This will allow incorporation of such risks into all public benefit delivery objectives of ELM scheme and is also supported by the recommendations of the Climate Change Committee[12].

[12] https://www.theccc.org.uk/publication/letter-environmental-land-management-elm-scheme/

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Annex 1: Method Description

Annex 1.1 Example of Data Collection Sheets

Cholderton - Data Request

Items requiring input/review from Cholderton

Items to be provided by eftec

	Total	Natural Capital Related Benefit														Non-natural capital		
		Cattle	Diary	Sheep	Cereals	Rye	Grazing	Seed	BPS	Timber	Renewable Energy	Habitat	Water Quality	Recreation	Air Quality	Climate	Burials	Rental income	Other
Output																			
Unit		no. cattle sold	litres	Head	tonnes	tonnes	Weeks	Yellow rattle	Income £	tonnes	kwh	Area under HLS (ha)	kg nitrate leaching	No.visits	kg PM2.5 removed	GHG flow (tCO_2e)	No burials	Rents and wayleave	?
Output																			
Unit price/value																			
Income/Benefit	-	-			-	-	-										-		
Costs																			
Feed	-																		
Milling	-																		
Hay/straw	-																		
Silage	-																		
Grass seed	-																		
Labour	-																		
Wood burial & grave digging	-																		
Other wages	-																		
Fitters & machinery repairs	-																		
Building Maint	-																		
Rental property exp	-																		
Energy/rates & water	-																		
Motor & haulage	-																		
Other fixed costs	-																		
Total costs	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-
EBITDA/net benefit	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Annex 1.2: Methods

Components of Natural Capital Balance Sheet

Asset values – sum of benefits dependent on natural capital assets over the accounting period – showing whether produced by in-hand or tenanted assets (where relevant) and whether accrue to the businesses or the wider society (which also includes other businesses). The asset values are estimated using the following supporting schedules:

- **Asset register** – showing a record of all natural capital assets within the boundary of the account. The type and size of benefits provided by natural capital assets are determined by the quantity (extent) and quality (condition) of those assets. Both extent and condition information and assumptions are recorded in the asset register.
- **Physical flow account** – showing the level of benefits provided by natural capital in physical terms that are relevant for each asset and benefit.
- **Monetary flows account** – showing the value of benefits provided by natural capital in monetary terms.

Liabilities – sum of the costs over the accounting period – showing costs of:

- Production costs - managing natural capital assets to produce private and public goods and services (e.g., crops).
- Maintenance costs - maintaining natural capital assets to improve their quantity and/or quality according to legal / statutory obligations or voluntary commitments.

Net asset value –sum of the asset values (benefits) less the liabilities (production and maintenance costs). A positive net natural capital value can only be interpreted as a sustainable position, if the account can demonstrate and document that maintenance provisions (i) are consistent with the baseline expected or projected trends, future flow projections and assumptions as informed by the assessment of future risks and (ii) are sufficient to maintain the quality and quantity of the natural capital assets. Otherwise, a positive net natural capital value shall be considered as uncertain and shall not be linked to a certain sustainable position. In the interpretation of the net natural capital value, the scope of the account, the extent to which asset values and maintenance costs have been possible to monetize and the result of the materiality assessment shall also be considered.

A.1.2.1 Benefits to the Estate

The methods used to calculate the benefits covered in the account are described in this section. All benefits are given a confidence rating in line with the guidance in Table A 1.

Table A 1: Description of confidence levels

Level of confidence	Description of confidence
High	Evidence is peer reviewed or based on published guidance and information so there is good confidence in using the data to support specific decisions and spending choices.
Medium	Science-based assumptions and published data are used but there is some uncertainty in combining them, resulting in reasonable confidence in using the data to guide decisions and spending choices.
Low	Evidence is partial and significant assumptions are made so that the data provides only order of magnitude estimates of value to inform decisions and spending choices.

Food Production

Estate food production and income are based on 2020 accounts or latest plans. Output is assumed to continue at current levels into the future. This assumption requires that soil condition is maintained.

Timber Production

Timber output was negligible for both Estates. Cholderton benefit is estimated by latest forecast grant income from farm plans.

Renewable energy

The renewable energy benefit is estimated by the latest forecast of solar photovoltaic output (kWh) on the Estate and valued using the income from farm accounts or plans. In the case of Cholderton, income is assumed at the guaranteed minimum income per acre based on agreed Heads of Terms with the energy provider, for Snoddington the farm plan income was used.

Woodland Burials

An income stream that was particular to Cholderton. The appeal of this service is highly dependent upon natural capital and hence has been included as a natural capital benefit. Value was based on farm plan income for 2020 and assumed to continue throughout the accounting period.

A.1.2.2 Benefits to wider society

Climate Regulation Impacts

Climate regulation is impacted (i) positively through carbon sequestration by woodland and farmland soils, and (ii) negatively through emissions of greenhouse gases from farm operations (e.g., nitrous oxides from decomposition of fertilisers, methane emissions from livestock, or combustion of fossil fuels from farm operations).

Sequestration

Woodland. For both Estates, sequestration in woodland was evaluated using UK average annual sequestration rates per hectare of woodland cover (5.7 tCO_2e/ha)[13]. Woodland sequestration rates vary with species, yield class, age of trees planted, and management regime. While calculating sequestration rates by individual woodland compartment using the Woodland Carbon Code[14] is possible, that level of effort was out of scope for these accounts. Therefore, the simple method of using the average rates was used.

Soil. At Cholderton, the organic land management regime is geared towards building soil carbon content, hence this is expected to be a significant benefit provided by the Estate's soils. Some historic data on soil organic matter levels was available (Table A 2) and whilst this suggests an increase of 4.6% in SOM over five decades, the low number of samples and the possibility that these results have been assessed by different methods, means that firm conclusions cannot be drawn. Furthermore, historic sequestration of carbon does not entail that sequestration will continue in the future, as soils will at some stage reach a certain saturation point for a given soil type and land use. However, views from the owner (based on visual inspection and better resilience to drought compared to neighbouring farms), suggest that the application of manures and the selective use of deep rooting legumes is still enriching the soil.

[13] ONS. (2020). Woodland natural capital accounts, UK: supplementary information. [online]. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/datasets/woodlandnaturalcapitalaccountsuksupplementaryinformation
[14] https://www.woodlandcarboncode.org.uk/

Table A 2: Historic Soil Organic Matter Results for Cholderton.

Year	SOM%	Number of Samples
1969	7.3	2
1975	8.6	3
2015	10.4	5
2021	11.9	5

Furthermore, soil sequestration is likely to vary with the phase of the ten year arable/leguminous leys rotational cycle. Based on the soil samples by field, the owner suspects that organic matter builds during the leys phase (by around 4% over 5-6 years of leys) and then falls by around 4% over 3-4 years of cropping. However, over the ten-year cycle it is possible that the average SOM % may increase steadily as the build phase adds slightly more carbon than the quantity of carbon removed in the arable phase. For example, the leys phase may peak at 12% SOM, falling to 8% at the end of the cropping phase, but the next cycle of maximum and minimum values may outturn at 12.5% and 8.5% respectively, hence each cycle may yield a slightly higher carbon content over time. The deep rooting leys and rotational ploughing also aim to sequester carbon deep into the soil (at around 45 cm in depth) and hence exploit the depth of soil to sequester more carbon.

In the case of permanent grassland, it is considered likely that soil organic matter will increase but at a slower rate due to the shallow depth of soils (30cm depth), and lower stocking density. Finally, given the age of woodland plots, it was assumed that woodland soils have more or less reached saturation point and hence woodland only sequesters carbon in vegetation (see above).

Whilst the data suggests a steady increase in soil organic matter at Cholderton over the last five decades, it is uncertain to what extent further carbon sequestration can be achieved over the next 50 years. However, given current sample levels (Table A 3) and that one sample result indicated 20% SOM, then it seems reasonable to expect the soil at Cholderton is capable of sequestering more carbon. Table A 3 highlights the assumptions made for current SOM levels and projected targets for SOM levels by 2070. The table also shows the equivalent rate of tCO_2e this would sequester per hectare per year. The evaluation assumed that soils reach saturation point and remain carbon neutral from 2070 onwards.

Table A 3: Soil Sequestration assumptions by land use and Scenario at Cholderton

Land Type	Current SOM%	Baseline target (to 2070)		Improvement plan target (to 2070)	
		Target SOM%	Annual sequestration (tCO_2e/ha)	Target SOM%	Annual sequestration (tCO_2e/ha)
Rotational arable/leys (average over 10-year cycle)	10%	11%	1.82	12%	3.65
Permanent grassland	12%	13%	1.22	14%	2.43

For Snoddington, there was one sample of soil organic matter levels (4.7%). One sample is insufficient to draw robust conclusions on overall organic matter levels across the farm, but this level is consistent with typical arable soils managed under intensive cultivation. No information was provided on rates of manure application. Consequently, no assessment could be made on the rate of carbon sequestration in the Estate's soils. Given that the land has been mainly used for high yield arable crops, the challenge is typically

to maintain soil organic carbon levels, rather than to actively sequester carbon overtime, hence the soil sequestration was assumed as zero.

Emissions from farming

Farm GHG emissions can occur from several sources:

- Methane emissions from enteric fermentation in livestock;
- Decomposition of manure (a range of gases);
- Nitrous oxide emissions from nitrogenous fertiliser, and
- Burning of fossil fuels, and electricity use in farm vehicles, plant and machinery.

Livestock methane emissions were estimated as average carbon dioxide equivalent by head of livestock type. The estimates used by livestock type are shown in Table A.4 and were calculated by dividing the total enteric fermentation greenhouse gas emissions for England by the total head of livestock. This gave estimates of 1.54 tCO_2e per head of cattle and 0.16 tCO_2e per ewe.

Table A.4: Calculation of enteric fermentation emissions by livestock type

	Total tCO_2e/yr in England[1]	Number of livestock in England[2]	Average tCO_2e/head
Beef cattle	5,649,271	3,664,000	1.54
Sheep	1,843,164	11,234,000	0.16

[1] Jones et al. (2019) National Atmospheric Emissions Inventory: Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland: 1990-2017.

[2] Defra (2019b) Livestock numbers in England and the UK https://www.gov.uk/government/statistical-data-sets/structure-of-the-livestock-industry-in-england-at-december

Livestock at Cholderton feed on sainfoin which makes a high proportion of the diet. Evidence from Mora Ortiz et al (2015) suggests that sainfoin can reduce enteric fermentation emissions by 12% has been applied to reduce the carbon dioxide equivalent emissions of livestock accordingly.

Manure also produces GHG emissions which have been estimated per head of livestock in a similar way to enteric fermentation emissions (see Table A.5). Manure from sheep has a very low footprint and has been excluded from the calculations.

Table A.5: Calculation of manure management emissions by livestock type

	Total tCO_2e/yr in England[1]	Number of livestock in England[2]	Average tCO_2e/head
Beef cattle	1,603,065	3,664,000	0.44

[1] Jones et al. (2019) National Atmospheric Emissions Inventory: Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland: 1990-2017.

[2] Defra (2019b) Livestock numbers in England and the UK https://www.gov.uk/government/statistical-data-sets/structure-of-the-livestock-industry-in-england-at-december

Fertiliser is only used at Snoddington emissions from which were based on factors of tCO_2e emissions per tonne of product applied based on Agrecalc (SAC Consulting, 2020). The two factors used were 2.9 tCO_2e, per tonne of Urea and 2.2 tCO_2e per tonne of Ammonium Nitrate 34%. The Estate provided fertiliser application rates for two typical crops and for the other three crops, average nitrate application rates by crop type were assumed based on John Nix Pocketbook (Redman 2020). Finally, fossil fuel and electricity emissions during the production of fertilizers were based on energy usage data provided by each Estate

for diesel and electricity use. These were converted to tCO_2e using BEIS standard reporting factors (BEIS 2020).

Valuation of Greenhouse Gas flows

The amount of tCO_2e sequestered and emitted is valued following the BEIS (2018) guidance using the non-traded central price, £72 per tonne of CO_2e in 2020. This is multiplied by the estimated tonnes of CO_2e sequestered. BEIS (2018) carbon values were released when the UK had an 80% carbon reduction commitment and are currently under review to reflect the UK government's net zero policy target. Latest advice (update April 2020) is to use the non-traded high estimate of the 2018 value range (£108 per tonne of CO_2e in 2020) for sensitivity analysis to reflect the potential range in value (BEIS, 2020), even though this higher level estimate has not been included in the account.

Air quality regulation

Air quality benefit included in the baseline natural capital account arises from the ability of different types of vegetation to remove pollutants from the air. This benefit is estimated by the amount of PM2.5 removed by woodland and the human health benefits of this removal.

Jones et al. (2017) modelled this benefit for the UK national accounts reflecting the variety of different levels of PM2.5 concentration, types and extent of vegetation and density of human population across the country. An update to this study (UKCEH and eftec, 2019) has produced estimates of PM2.5 removal per hectare of woodland by local authority across the UK. The benefit of removal is estimated as the avoided health care cost (UKCEH and eftec, 2019).

The baseline and future LMP accounts for both Estates shows the per hectare benefit from the UKCEH and eftec (2019) model for the local authority area of Hampshire multiplied by the total woodland area in the Estate (from the natural capital asset register).

Water quality regulation

Both Estates fall within a Nitrate Vulnerable Zone (NVZ), and there have been problems with diffuse pollution to groundwater in the area. Nitrate loading progressively emerged as a significant problem to water quality in the local area, with records showing a steady increase in nitrate concentration in the main Cholderton & District boreholes since the mid-1970s. The main cause has been diffuse pollution arising from the cumulative effects of fertiliser use by farms in the catchment. Concentrations were starting to reach drinking water standard limits, and in 2016, the Cholderton and District Water Company had to install a nitrate removal plant. The leasing and running costs added £71,000 to the annual operating costs of the water company[15]. By early 2021, steps to reduce diffuse pollution have reduced concentrations and there is currently no requirement for nitrate removal. Consequently, the plant is in the process of decommissioning, having been in operation for the last five years. In the first natural capital account for Cholderton (eftec, 2018) a cost for the dis-benefit of nitrate leaching was attributed to the 'typical farm' based on estimates of nitrate application and the costs of nitrate removal. However, given that this cost is no longer incurred, this dis-benefit has now been excluded from the account.

The organic system at the Cholderton Estate excludes the use of artificial fertilisers and sprays so avoiding potential pollutants to both surface water and groundwater. The approach to assessing the benefit of this practice was to assume that this contributes to maintaining the current status of the River Bourne

[15] Private communication – Trustee of the Cholderton & District Water Company.

waterbody (moderate in 2019) and avoiding a decline from moderate to poor condition. The value of maintaining the current status is equated to the NWEBS central value for this water body's shift in status between poor and moderate(£827,000 in 2012). Rebased to 2021 this is £953,418, or £ 20,285 per km of river. This value is apportioned to Cholderton on the basis of the proportion of the River Bourne running through the Estate, i.e. 1km of the River. This means £20,285 was assumed as the annual water quality benefit of the Estate's land management style.

Snoddington land management entails significant use of artificial fertiliser & sprays and it is difficult to predict the impact of these inputs without more data and hydrological modelling. Therefore, while no public disbenefit could be calculated, it is clear that no benefit to maintaining current quality can be attributed either. Therefore, there is no value associated with water quality for Snoddington.

Recreation

Recreation in nature generated physical and mental health benefits and wellbeing. Recreational benefits in the two estates are linked to the number of visits made using public paths. The online tool ORVal[16] is used to for this purpose. The tool also breaks down the estimated number of visits and associated welfare value by socio-economic group. The physical flow (number of annual visits) and monetary value (welfare value) is assumed to remain constant over the accounting period.

It should be noted that the data from ORVal takes into account the location of the recreation asset, surrounding population, habitat type(s) and local alternatives, but makes the assumption that accessible green space is in average condition for its type. If the green space is in a better (worse) condition than average, this will likely have higher (lower) values for number and welfare value of visits. Similarly, as the model underlying ORVal is based on MENE data[17], it does not take into account visits by children or overseas visitors to the UK.

Biodiversity

Biodiversity has an intrinsic value in itself and contributes to all ecosystem services provided, even though it is often not possible to apportion a value to that contribution. We are testing a new approach to valuing biodiversity in these accounts. This approach is based on the proxy of creating the same level of biodiversity elsewhere. The level of biodiversity is estimated using the Defra biodiversity metric (Crosher et al 2019). The cost is estimated using the likely cost of a biodiversity credit (Defra, 2019).

The units attributed to each Estate was calculated as the difference between a current estimate of biodiversity units and a counterfactual case of intensive agricultural use. This was a desktop exercise, and no condition assessment was carried out. Condition ratings were based on views from owners and the member of the Hampshire & Isle of Wight Wildlife Trust who was involved with the project.

[16] 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 Recreational. https://www.leep.exeter.ac.uk/orval/

[17] See: Natural England (n.d.) https://www.gov.uk/government/collections/monitor-of-engagement-with-the-natural-environment-survey-purpose-and-results

The assumed habitat types and condition for Cholderton is shown in Table A.6 and for Snoddington in Table A.7.

Table A.6: Assumed biodiversity habitat and condition for the Cholderton Estate

Habitat/feature	Area (ha)	Current Habitat	Counterfactual assumption
Grassland	440	Lowland meadow (very high distinctiveness score) in good condition	Modified grassland in moderate condition
Arable/grass rotation	440	Agricultural land (low distinctiveness and condition score)	Same
Woodland	120	Lowland mixed deciduous woodland in moderate condition	Lowland mixed deciduous woodland in poor condition
Total	1,000		
Linear features	**km**		
Hedgerows	96	Native species rich hedgerow in good condition	Native hedgerow in poor condition

Table A.7: Assumed biodiversity habitat and condition for the Snoddington Manor Estate

Habitat/feature	Area (ha)	Current Habitat	Counterfactual assumption
Grassland	8	Lowland calcareous grassland (high distinctiveness score) in moderate condition	Modified grassland in poor condition
Arable/grass rotation	540	Agricultural land (low distinctiveness and condition score)	Same
Woodland	51	Lowland mixed deciduous woodland in moderate/low condition	Lowland mixed deciduous woodland in poor condition
Total	599		
Linear features*	**Km**		

Note*: hedgerow length was not available. Some hedgerows were judged to be in good condition.

These assumptions produced the scores shown in Table A.8 and Table A.9.

Table A.8: Estimated biodiversity metric scores for the Cholderton Estate

Habitat/feature	Area (ha)	Current score	Counterfactual score	Difference
Grassland	440	10,560	1,760	8,800
Arable/grass rotation	440	880	880	-
Woodland	120	1,440	720	720
Sub-total	**1,000**	**12,880**	**3,360**	**9,520**
Linear features	**km**			
Hedgerows	96	1,152	192	960
Total units		**14,032**	**3,552**	**10,480**

Table A.9: Estimated biodiversity metric scores for the Snoddington Manor Estate

Habitat/feature	Area (ha)	Current score	Counterfactual score	Difference
Grassland	8	96	16	80
Arable/grass rotation	540	1,080	1,080	-
Woodland	51	459	306	153
Total units	**599**	**1,635**	**1,402**	**233**

All biodiversity units were valued at £11,000 per unit, an assumption taken from Defra (2019), as an average cost of a biodiversity unit.

A.1.2.3. Liabilities

Natural capital maintenance costs

The costs the Estate incurs to maintain (or enhance) the quality and quantity of natural capital assets are called 'maintenance costs'. If the Estate has legal obligations to maintain these assets (e.g., agri-environment schemes, biodiversity offsets, or any other regulation), they should be accounted as 'legal obligations'. All other costs that the Estate incurs voluntarily should be recorded as 'other maintenance'.

For Cholderton, the main costs assumed in meeting agri-environment obligations involved the provision of seed (expense itemised in the 2020 farm plan), and farm labour required to sow seed, manage margins and buffer strips and maintain the species rich grassland. There were no records of time utilised on these activities, so it was assumed that 10% of all farm labour time was employed on these tasks, hence 10% of the farm labour bill was included in the maintenance cost estimate.

For Snoddington, there were no legal maintenance obligations, but the Estate did have a small provision for woodland management expenses, and these were used as the basis of estimate for 'other maintenance' activities.

Overheads

Both Estates incur substantial overheads (including, labour, repairs, energy, depreciation of equipment and finance costs). In the absence of detailed records differentiating between production and maintenance costs, overheads are added in their entirety.

Production costs

These are costs incurred to produce the private and public benefits from natural capital accounts. Examples include costs of harvesting timber, extracting minerals, producing food, storing water, operating recreational activities. Costs can be capital or operating costs. They can include spending on labour, machinery, energy, overheads and so on. Production costs need to be itemised to match each benefit produced.

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