# Developing a simple Natural Capital Account (NCA) for the Cashel Native Forest Centre

Placement report by Eponine Loridant

Supervised by Prof. Marc Metzger (University of Edinburgh) and
Dr. Peter Philips (Cashel Native Forets Centre Trustee)

THE UNIVERSITY OF EDINBURGH

CSFL
CENTRE FOR SUSTAINABLE FORESTS AND LANDSCAPES

March 2021 – July 2021

## Abstract

From flood mitigation to pollination, ecosystems provide a wide range of benefits to society. Considering the biodiversity crisis and climate emergency there is growing recognition of the importance to manage ecosystems sustainably. Natural Capital Accounting, by measuring flows and stocks of natural assets, is one emerging approach to support sustainable ecosystem management. Following from insightful international and national Natural Capital Accounts (NCAs) there have now been a few attempts to develop Natural Capital Accounts in Scotland. The Cashel Forest Trust, a charity linked to the Royal Scottish Forestry Society, has expressed the desire to develop accounts for the Cashel site, a 1200-hectare former hill farm within the Loch Lomond & The Trossachs National Park. This report summarises a first attempt to develop a NCA for Cashel as part of a four-month student placement.

The Natural Capital Protocol, combined with the United Nations System for Environmental Economic Assessment – Ecosystem Accounting framework provided a robust approach for the NCA. Given time constraints, it was agreed with the Cashel Trustees to focus on five natural assets: forested land (152 ha); heathland (525ha); grassland (89 ha); peatland (487 ha); and water courses (0.2 ha). Simple and more complex methods to quantify the ecosystem services for the physical flow accounts and to identify feasible valuation methods for the monetary flow accounts were identified in the literature and implemented. The following table summarises the physical and monetary flow accounts and indicate the uncertainties in a simple traffic light. Poor data availability and substantial assumptions limit the confidence for many of the ecosystem services, but a few provisional services could be quantified and valued with more confidence.

| **Ecosystem service** | **Physical flow (per year)** | **Monetary flow (over 100 years)** |
|---|---|---|
| Timber | 50 tons | £24,000 |
| Venison | 40 deer | £291,000 |
| Carbon storage | 4,133 tons | £92,573,000 |
| Renewable energy | 1,377,556 kWh | £2,438,000 |
| Recreation (avoided health care costs) | 10,000 active visitors | £600,000 |
| Recreation (welfare) | 10,000 active visitors | £16,388,000 |
| Recreation (time-use) | 15,000 visitors | £79,597,000 |
| Recreation (visited habitats) | 15,000 visitors | £7,596,000 |
| Recreation (costs of production) | 15,000 visitors | £1,358,000 |
| Recreation (willingness-to-pay) | 15,000 visitors | £194,000 |
| Education (production costs) | 3,750 children | £339,000 |

Natural Capital Accounting methods for rural land holdings in Scotland are in an experimental phase, and the data and methods used here have many limitations. Nevertheless, this study provides the Cashel Trustees with first insight into the value of the of ecosystem services provided by Cashel. In time, the methods and data used in this report can be improved and the accounts updated to improve accuracy of the NCA.

**Abstract** 2

**1. Introduction** 5

1.1. Natural Capital – recognising benefits from nature 5

1.2. Approaches for Natural Capital Accounting 5

1.3. Objectives 6

**2. Methods** 8

2.1. Overall methods 8

2.2. Creating the Ecosystem Extent account 10

2.3. Creating the Ecosystem Condition account 10

2.4. Creating the Ecosystem Service account 10

**3. Results** 21

**3.1. Stage 1 : Why ? (Risks, opportunities, relevance to decision-making)** 21

3.1.1. Relation of Cashel with Natural Capital Accounting 21

3.1.2. Risks and opportunities 21

3.2.3. Impact on decision-making 21

**3.2. Stage 2 : what ? (Objectives, selection of assessed impacts and dependencies)** 22

3.2.1. Objective 22

3.2.2. Stakeholders 22

3.2.3. Scope 22

3.2.4. Natural assets 22

3.3.5. Impacts and dependencies 23

**3.3. Stage 3 : how ? (Measurements, valuation)** 23

3.3.1. Extent account 23

3.3.2. Woodland products 26

3.3.3. Carbon storage 27

3.3.4. Renewable energy 28

3.3.5. Recreation 29

3.3.6. Education 32

**4. Limitations and uncertainties** 33

4.1. Land cover data 33

4.2. Woodland products 33

4.3. Carbon storage 34

4.4. Recreation and education 34
4.5. Choice of ecosystem services 34
**5. Conclusion 35**
**References 36**
**Appendix A: condition account 38**
**Appendix B: inputs from Cashel's Trustees 42**
**Appendix C: data sources 49**

# 1. Introduction

## 1.1. Natural Capital – recognising benefits from nature

From flood mitigations to pollination, ecosystems provide a wide range of services that benefit human societies. The recognition of the importance of this Natural Capital, defined as 'the renewable and non-renewable stocks of natural assets which includes geology, soil, air, water, and all living things' by the Scottish Forum on Natural Capital[1], is increasingly considered as a first step towards achieving support for invest in nature. and manage it sustainably to continue enjoying these benefits. Natural Capital accounting is a tool to measure the changes in the stock of natural capital and to integrate the value of ecosystem services into accounting and reporting systems.

Natural Capital Accounting consists of:

- selecting a register of Natural Capital assets that can be measured, mapped and assessed in terms of their condition,
- quantifying the physical flow of ecosystem services provided by these assets,
- attributing a monetary value to this physical flow and finally,
- producing a balance sheet.

The Cashel Forest Trust, a charity fund linked to the Royal Scottish Forestry Society, has expressed the desire to develop a Natural Capital Account for the Cashel's site, a 1200-hectare former hill farm located within the Loch Lomond & The Trossachs National Park. The site's management aims at "to demonstrate the restoration and regeneration of Scotland's native woods through sound forestry practice for the benefit of the public." Natural Capital Accounting was seen a potential reporting mechanism to communicate the public value of its activities.

## 1.2. Approaches for Natural Capital Accounting

Methods for Natural Capital Accounting have developed rapidly over the last decade, and standardised approaches are promoted by the United Nations, the European Union and many national governments. Since 2019, Scottish Government produces annual Natural Capital Accounts[2]. There have also been various pilot studies to understand how Natural Capital approaches can support sustainable land management[3].

Widely used approached to Natural Capital Accounting include:

- Corporate Natural Capital Accounting[4], which is tailored for the private sector. Its specificity is that it includes maintenance costs and that it overall aims at helping managers to consider the natural capital when making financial decision. However, this was not the objective of Cashel's Board of Trustees.

[1] https://naturalcapitalscotland.com
[2] https://www.gov.scot/publications/scottish-natural-capital-accounts-2020/
[3] https://sefari.scot/research/using-natural-capital-approaches-to-support-sustainable-land-management-in-scotland
[4] Corporate Natural Capital Accounting (naturalcapitalcommittee.org)

- The United Nations System of Environmental Economic Accounting - Central Framework (UN SEEA - CF)[5], which provides standardized methods for individual environmental assets. It is used was developed to support and compliment national accounts.
- The Capitals Coalition Natural Capital Protocol[6], a decision-making framework that enables organisations to identify, measure and value their direct and indirect impacts and dependencies on natural capital. It has been used in various land-based pilots in Scotland, including the recent Scottish Forestry pilot for a planting site at Larriston in the Scottish Borders (AECOM 2020).

- The United Nations System of Environmental Economic Accounting - Ecosystems Accounting (UN SEEA - EA)[7], which provides a flexible protocol for five successive accounts:
    1. Asset extent (area for each considered ecosystem);
    2. Asset condition (biodiversity, soil condition, spatial fragmentation, etc. of each considered ecosystem);
    3. Ecosystem services physical flow (volume of timber production, tonnes of stored carbon, …);
    4. Ecosystem services annual monetary value (monetary flow from timber production, …);
    5. Overall monetary value (aggregation with a discount rate of the annual values over a specified asset lifetime).

For Cashel, it was decided to combine the Natural Capital Protocol to frame the process for developing the accounts, and the United Nations System for Environmental Economic Assessment – Ecosystem Accounting to structure separate accounts. The most appropriate methods for quantifying and valuing ecosystem services were identified through literature review.

## 1.3. Objectives

Following consultation with the Cashel Trustees the objectives were agreed for this study:

1. To demonstrate the application of a natural capital approach by a landowning charity and to contribute to wider natural capital policy and practice;
2. To provide a robust system of accounts and supporting method statements for tracking changes in the condition of Cashel's natural capital assets (e.g. woodland, peatland), physical flows of key ecosystem services and the value(s) of the private and societal benefits provided by these ecosystem services; and
3. To generate data and evidence on the benefits and value(s) of Cashel's natural capital to support funding applications, for use in promotional material (e.g. with local communities), demonstrating compliance with the LRRS Land Ownership by Charities protocol

This work would then provide the basis for the Trustees to explore if and how data and evidence on natural capital impacts, dependencies and values could be used to inform practical land use management decision-making at Cashel (i.e. where and how does application of the NCP add

[5] SEEA Central Framework | System of Environmental Economic Accounting
[6] Natural Capital Protocol – Capitals Coalition
[7] Ecosystem Accounting | System of Environmental Economic Accounting

value to operational and strategic planning at Cashel) and to decide whether the accounts should be refined and updated in the future.

# 2. Methods

## 2.1. Overall methods

The Capitals Coalition Natural Capital Protocol[8] has been successfully used in various pilot projects in Scotland[9]. It is structured around four stages that address specific questions (see Figure 2.1), providing an accessible explanation of the framework for structuring the activities. The final stage, applying the NCA in decision making, falls outside the scope of this study, but can be completed by the Trustee after completion of this project.

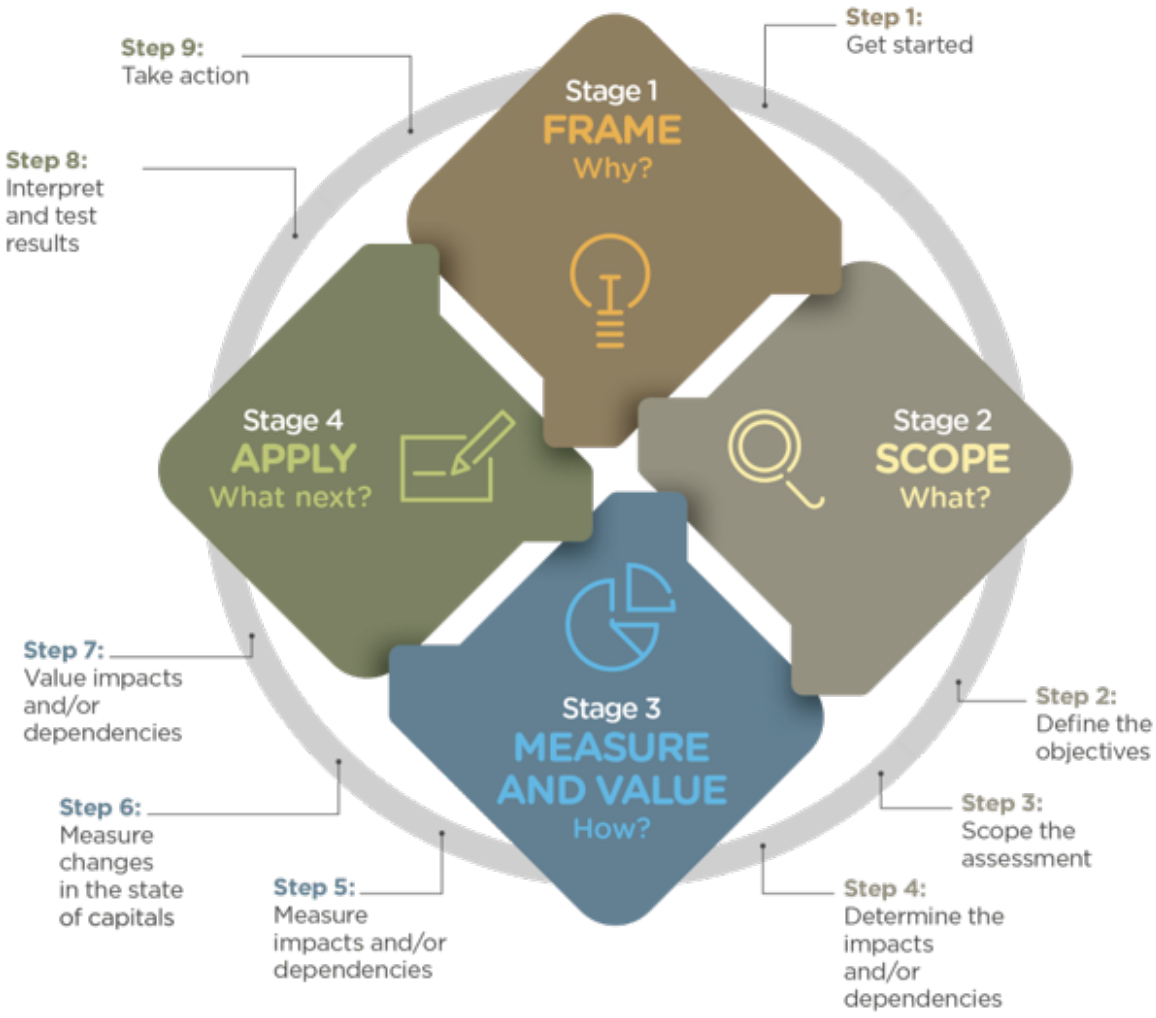


**Figure 2.1: Overview of the natural capital protocol.**

**Stage 1** involved discussions between the intern Eponine Loridant and her advisers Prof. Marc Metzger and Dr. Peter Philips and a literature review of the approaches to Natural Capital Accounting, on Ecosystem Services and their valuation tools. It also featured.

In **Stage 2**, Eponine Loridant developed a proposal clarifying the objectives and scope of the project, which discussed and annotated by the Trustees.

[8] https://capitalscoalition.org/capitals-approach/natural-capital-protocol/

[9] https://sefari.scot/research/using-natural-capital-approaches-to-support-sustainable-land-management-in-scotland

Within **Stage 3** (Measure and Value), Eponine Loridant created the NCA following the United Nations System of Environmental Economic Accounting (UNSEEA) - Ecosystems Accounting framework[10]. SEEA EA constitutes an integrated and comprehensive statistical framework for organizing data about habitats and landscapes, measuring the ecosystem services, tracking changes in ecosystem assets, and linking this information to economic and other human activity. Figure 2.2 illustrates the five types of accounts that will be created:

1. ECOSYSTEM EXTENT accounts record the total area of each ecosystem, classified by type within a specified area (ecosystem accounting area). Ecosystem extent accounts are measured over time in ecosystem accounting areas (e.g., nation, province, river basin, protected area, etc.) by ecosystem type, thus illustrating the changes in extent from one ecosystem type to another over the accounting period.

2. ECOSYSTEM CONDITION accounts record the condition of ecosystem assets in terms of selected characteristics at specific points in time. Over time, they record the changes to their condition and provide valuable information on the health of ecosystems. *There was insufficient time to create a complete ecosystem condition account as part of this study.*

3. & 4. ECOSYSTEM SERVICES flow accounts (physical and monetary) record the supply of ecosystem services by ecosystem assets and the use of those services by economic units, including households.

5. MONETARY ECOSYSTEM ASSET accounts record information on stocks and changes in stocks (additions and reductions) of ecosystem assets. This includes accounting for ecosystem degradation and enhancement. *Changes in stocks can only be assessed when comparing two time periods and are therefore not included in this report.*

The specific methods for creating the accounts are described in detail in the following sections.

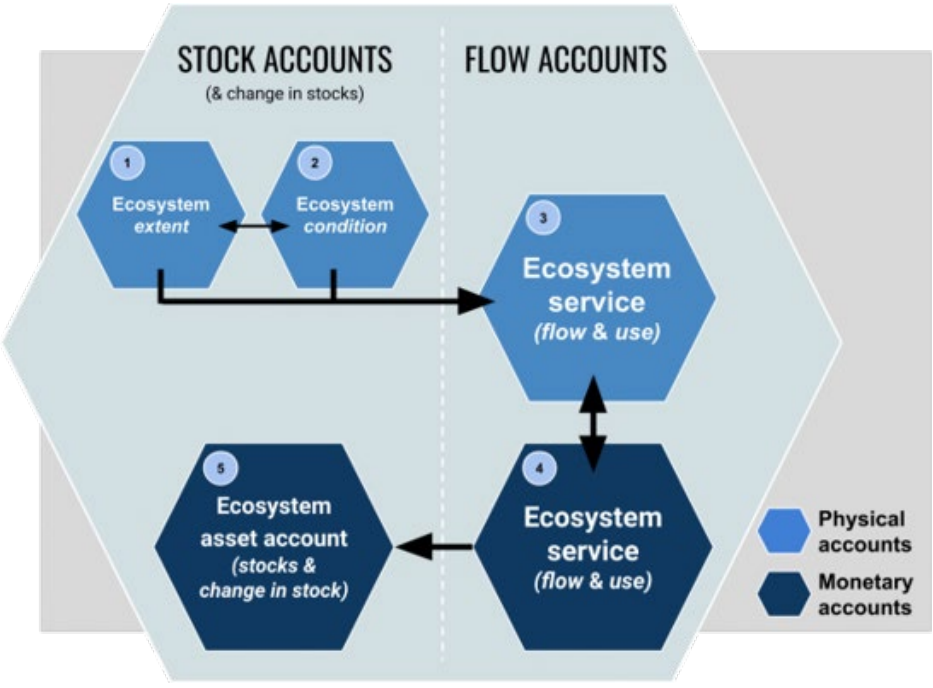


**Figure 2.2: Overview of the accounts and their sequence in the United Nations System of Environmental Economic Accounting - Ecosystems Accounting method**

[10] https://seea.un.org/ecosystem-accounting

## 2.2. Creating the Ecosystem Extent account

The Ecosystem Extent account forms record of the total area of each ecosystem type within Cashel. Ecosystem extent accounts are measured over time, thus illustrating the changes in extent from one ecosystem type to another over the accounting period.

Although some local habitat data exists for Cashel, they are inconsistent and are not updated regularly. It was therefore decided to use the new SLAM-MAP land cover map[11], developed by Space Intelligence. It provides a high resolution (20x20m) habitat map distinguishing 22 habitat types from the European Nature Information System (EUNIS) level II and is expected to be updated annually. These EUNIS habitat types can be reclassified into ecosystem classes for the account. g these habitats into ecosystem classes.

## 2.3. Creating the Ecosystem Condition account

The Ecosystem Condition account forms a record of the condition of ecosystem assets in terms of selected characteristics. Over time, they record the changes to their condition and provide valuable information on the health of ecosystems. The Scottish Natural Capital Accounting and Defra principles[12] give a more detailed description of this account's content. Examples of characteristics that can be included in the Ecosystem condition account include:

- Volume (timber biomass, water flow, etc.),
- Biodiversity (number of species, etc.),
- Soil condition (carbon content, water content, etc.),
- Ecological condition (presence of invasive species, water quality, etc.),
- Spatial configuration (fragmentation),
- Management (degree of protection, etc.).

This study initially aimed at producing a condition account through the following process:

- Reviewing of possible indicators for each natural asset
- Discussing and choosing indicators with the Cashel's Trustees based on their interest and data collectability
- Collecting data and reporting Data gathering and/or collection

Unfortunately, due to time constraints only the first step could be completed. Appendix A provides an overview of possible indicators that could be used to create a full ecosystem condition account in future.

## 2.4. Creating the Ecosystem Service account

The Ecosystem Service account consist of physical flow and monetary flow accounts for selected ecosystem services. In consultation with Peter Philips and the chair of the Board of Trustees it was decided that the following ecosystem services were most relevant to be included in the ecosystem service account:

- Woodland products
- Carbon storage
- Renewable energy
- Recreation
- Education

[11] Scotland's landcover new habitat map, released as open data by creators Space Intelligence in 2021. Full original datasets downloadable here.

[12] Principles of Natural Capital Accounting - Office for National Statistics (ons.gov.uk)

Methodologies for creating the physical flow and monetary flow accounts for the listed ecosystem services is described below. Where relevant, different options with varying degrees of in complexity and accuracy are described. For this study the most straightforward option was usually used, but the alternatives are described to allow for possible future elaboration of the accounts.

There are two parameters that must be set for the ecosystem service account: the asset lifetime and the discount rate. For both parameters we followed the Scottish ONS and Defra principles paper for renewable assets. The asset lifetime was set at 100 years. This means that it was considered that the ecosystem services could be provided over this period. In fact, if managed sustainably, renewable assets (as the assets featured in this study) can provide services indefinitely. But it should also be reminded that considering a longer lifetime implies higher uncertainties. The discount rate allows the future value of the considered ecosystem service to be converted into present value. We used 3.5% for the first 30 years, 3% until the 75th year and 2.5% after the 75th year.

---

### 2.4.1. Woodland products

Cashel's woodlands provide different products, here regarded as provisioning ecosystem services. Timber and venison were considered the most relevant woodland products to include in the NCA.

---

#### Timber

*Physical flow account*

The physical flow can be evaluated by two different methods.

- Option 1: **observed sold timber**: The simplest method is to use the observed amount of sold timber. It has been previously used by Clark et al. (2020). It requires annual sales data as well as projections, which could be provided by Cashel's administration. This method has the advantage of being straightforward and objective.
- Option 2: **modelling timber production**: A more complex method, recommended by the UN SEEA EA (Tier 2) and the EU Ecosystems services accounting, is to estimate timber production by modelling tree growth and mortality. Several modelling methods can be used to calculate annual growth applied:
    - an ecosystem contribution factor (Vallecillo et al. (2019)), that reflects how much of the growth can be attributed to the ecosystem, the rest being linked to human activities such as maintenance work;
    - an annual growth factor of the harvested species (Pingoud et al. (2006));
    - the cultivated surface of each harvested specie;
    - the natural tree mortality (Senf et al. (2018)).

    The formula to calculate annual growth is then:

    > *Annual growth = Sum on harvested species of [Ecosystem contribution factor * (annual growth per surface - natural mortality per surface) * cultivated surface]*.

    This method provides information on the maximum timber production and can be used to monitor harvested volumes to sustainable levels, that do not exceed growth.

At Cashel, harvest will start during winter 2021. The choice was thus made to use both methods, as the observation method will only be an estimation of the future harvest whereas the modelling method will enable a sustainable management.

*Monetary flow account*

The monetary value of timber production can be assessed by three different methods:

- Option 1: **Market price**, which could be provided by the Cashel Trustees. This approach is recommended by the UN SEEA - EA and the European Union Ecosystem services accounting, and used in the Clark et al. (2020) mentioned above.
- Option 2: **Stumpage price**, suggested by the Scottish Office for National Statistics (ONS), which are provided by the Forestry Commission Timber Prices Indices. This was also used by Cryle et al. (2017).
- Option 3: **Resource rent price**, which requires knowledge of the incomes and liabilities, and thus of the selling price, the maintenance costs, the production costs such as fertilizers purchases, staff wages, … The value would then be:

> *Net annual value = Incomes - Liabilities = Physical flow * selling price - various costs*

This method is recommended by the Scottish ONS and Defra principles paper.

The only value provided by Cashel's trustees is the expected surplus, which led us to use it as a form of resource rent price method.

The final formula is:

> *Monetary flow = Sum on years of [Physical flow * value * (1 - discount rate)].*

*Stock account*

The collection of local data on tree density should enable the future calculation of the stock account for timber. However, as these data do not exist yet (partly because the forest plantations are young), this account could not be assessed within this study.

---

**Venison**

The other woodland product considered in this study is venison.

*Physical flow*

The physical flow of venison can be measured with the number of killed animals. We will use this method as these data are available.

*Monetary flow*

In general, the use of a market price recommended by the UN SEEA - EA and the European Union Ecosystem services accounting. However, we will have to use a slightly modified version of the market price. Venison is indeed the source of a monetary flow as a hunting lease is sold. But the value of this lease is not calculated per unit of physical flow, ie per killed animal, but rather as a whole. This is why we will directly use the annual value of the hunting lease as the annual monetary flow.

The final formula is :

| *Monetary flow = Sum on years of [Value * (1 - discount rate)].* |
|---|

*Stock account*

The collection of data on Cashel's site on the number of deer should enable the calculation of this account. However, it could not be done within the time constraints of this study.

---

### 2.4.2. Carbon storage

Carbon is stored by vegetation and soil. This carbon sequestration is defined as a regulating ecosystem service and will be here valued.

*Physical flow account*

The physical flow depends on two carbon accounts, the emissions and the sequestration, which are usually regarded as negative emissions.

The emissions can be calculated by adding:

- **Emissions from the soil due to ground preparation**: operations such as ploughing generate carbon emissions. These emissions should be considered separately when calculating the annual physical flow, as they are one-off. The method used to calculate these is based on AECOM (2020).
- **Emissions from machines**: all operations such as heating up buildings, conducting maintenance work or harvesting timber generate emissions. This was assessed by Markewitz (2006).
- **Emissions from harvested timber products**: the carbon stored in harvested timber has to be deduced from the total carbon storage, as it is released during its use. This follows guidelines from the IPCC (Guidelines for National GHG Inventories, Volume 4, Chapter 12, Table 12.4, IPCC) and was assessed by Profft (2009). The AECOM applied this method.

The sequestration can be evaluated by two main methods:

- Option 1: **estimates per habitat type**: the simplest method is to consider standard emissions rates by different habitat types and calculate based on Cashel's habitat extent. The emissions data could be provided by the UK National Emissions Inventory, the Centre for Ecology and Hydrology, the Woodland Carbon Code or the Royal Society for the Protection of Birds (RSPB). This method was used by the Scottish NCA (2020), Dickie et al. (2020), Clark et al. (2020).
- Option 2: **calculation based on locally collected data on vegetation and soil**: another method would be to use the vegetation and soil characteristics at Cashel. It could be based on modelisation, using the values for biomass per hectare per habitat type and the soil emissions rates per habitat type provided by the IPCC (Guidelines for National GHG Inventories, Volume 4, IPCC), or on observation, weighing the vegetation and measuring the soil carbon content, as did Friggens et al. (2020). We would then convert the biomass into carbon stock.

For Cashel we will use the first option because local data do not exist yet. We will use the data provided by the RSPB, as did Clark et al. (2020). Cashel's trustees did not provide values for fuel and other pollutants consumption. Thus we have not been able to include these emissions in our calculation.

The formula is:

> *Physical flow = Sum of harvested products of [emissions per kilogram of product * harvest weight] - sum on habitat types of [emissions per hectare * habitat extent]*

*Monetary flow account*

The monetary flow can be assessed by two methods:

- Option 1: **non-traded market price**, which considers the value of stored carbon. This method is widely used (Scottish NCA (2020), Cryle et al. (2017), Dickie et al. (2020), AECOM (2020)) and is recommended by the Scottish ONS and Defra principles paper. The exact value is provided in the Green Book supplementary guidance of HM Treasury. This value increases with time, following governmental indications.
- Option 2: **market price**, which would be provided by the Cashel's administration. Using market price is recommended by the UN SEEA - EA and the EU Ecosystem services accounting whenever possible. This method was used by Cryle et al. (2017) and by the AECOM (2020). Different market prices can be used: the studies mentioned used values provided by the European Union European Trading Scheme (ETS) and the Woodland Carbon Code respectively.

For Cashel we will use the central traded market price given by HM Treasury, so as to be consistent with the UN SEEA – EA guidelines.

The final formula is:

> *Monetary flow = Sum on years of [Physical flow * value * (1 - discount rate)]* where the physical flow for the first year includes emissions due to ground preparation.

*Stock account*

The carbon stock account can be calculated by adding the carbon content of the above-ground and below-ground vegetation and that of the soil per habitat. The IPCC provides the needed data in its 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use.

The formula is:

> *Carbon stock = Sum on habitat types of [(Weight of the above-ground vegetation * carbon content of the above-vegetation + Ration of above-ground to below-ground vegetation * weight of the above-ground vegetation * carbon content of the above-vegetation + Soil carbon content) * Habitat extent].*

---

### 2.4.3. Renewable energy

Cashel's assets enable the production of renewable energy, which is a provisioning ecosystem service. We will here study the value of hydro-electric energy production, following the indications of the trustees.

*Physical flow account*

The physical flow can theoretically be evaluated through two methods:

- Option 1: **observed production**: the simplest method is to use the amount of real production, as Dickie et al. (Dickie, I., Royle, D. & Neupauer, S. 2019. Testing a natural capital approach on SNH land. Scottish Natural Heritage Research Report No. 1144.). This method is recommended by the UN SEEA under the Energy section. It has the advantage of being objective and straightforward.
- Option 2: **potential production**: another method would be to assess the maximum possible production, given Cashel's assets. This could help in the process of decision-making of future investments. However, it would not be a valuation of Cashel's actual natural capital.

We will use the observation method, as it follows general UN guidelines and is more objective.

*Monetary flow account*

The monetary flow can be assessed by two methods:

- Option 1: **resource rent price**: the monetary flow would be calculated based on financial outputs of energy sales and liabilities (maintenance cost of the infrastructures, cost of staff…). The value would then be:

  *Net annual value = Incomes - Liabilities.*

  This is recommended by the Scottish ONS and Defra principles paper.
- Option 2: **market price**, which would be provided by the Cashel Trustees. This approach is recommended by the UN SEEA - EA and the EU Ecosystem services accounting, and used in the Dickie et al. (2019) mentioned above.

For Cashel we will use the resource rent price, with values provided by the Cashel Trustees.

The final formula is:

*Monetary flow = Sum on years of [Physical flow * value * (1 - discount rate)]*

*Stock account*

The calculation of a stock account for renewable energy would require further literature review, which could not be done within the time constraints of this study.

---

### 2.4.4. Recreation

Cashel is used for recreation purposes. We can distinguish different ecosystem services related to this:

- when Cashel is used as a ground for physical activity, it results in health benefits;
- aesthetics is regarded as a cultural ecosystem service (Defra principles); and
- mental benefits can be withdrawn from the contact with nature.

We will here assess the health benefits and the other benefits separately.

---

## Health benefits

*Physical flow account*

The physical flow is here the number of active visits made every year. We define an active visit as featuring at least 30 minutes of physical activity such as hiking, running or cycling.

The physical flow can be evaluated through three methods:

- Option 1: **observed number of active visits**: the simplest method is to count active visits. It has the advantage of being objective and straightforward.
- Option 2: **estimated number of active visits based on local data**, which consists in estimating the percentage of visits that are active. This method was used by Clark et al (2020) and Dickie et al. (2019).
- Option 3: **estimated number of active visits based on national data**, which would use the results of the Outdoor Recreation Valuation Tool (ORVAL), the Great Britain Tourism Survey or the Monitor Engagement with the Natural Environment (MENE) survey to calculate the number of active visits made at Cashel every year.

We will use an estimated number of visitors provided by Cashel's trustees. We consider local data, even if estimated, as more accurate than national data. However, in the future, the collection of more precise data by Cashel's management could enable a refinement of this account.

*Monetary flow account*

The monetary flow can be assessed by two complementary methods:

- Option 1: **avoided health care costs**, which considers the costs for the society (through the National Health System and the Clinical Commissioning Groups notably) associated with the pathologies known to be reduced by physical activity. This method was used by Scottish NCA 2020 and by Cryle et al. (2017). Cashel's trustees estimate that visitors spend in average 4 hours on site. Thus one visit at Cashel would enable an active visitor to meet the recommended level of activity for a week, which is between 150 and 300 minutes of moderate-intensity aerobic physical activity (World Health Organization, 2020). The final formula would then be:

> *Monetary flow = Sum on years of [ (Number of visitors * cost of inactivity per person per year / number of weeks in a year)* (1 - discount rate)] .*

- Option 2: **welfare value**, which uses the value of Quality Life Years (QALY), that is, years lived in perfect health, gained through physical activity. This method was used by Clark et al (2020), Dickie et al (2019) and Cryle et al (2017). Clark et al (2020) provides a value of gained QALY when doing 30 minutes of moderate physical activity per week during a year. We considered that one visit at Cashel would enable active visitors to meet their weekly level of activity. The final formula would then be :

*Monetary flow = Sum on years of [ (Number of visitors* annual welfare value / number of weeks in a year)* (1 - discount rate)] .*

For Cashel we will apply and compare both methods.

*Stock account*

There is no stock account for recreation as this ecosystem service is not limited.

---

## Other benefits from recreation

*Physical flow account*

The physical flow can be defined as the number of visits made every year. It can be evaluated by two methods:

- Option 1: **observed number of visits**: the simplest method is to count visits. It has the advantage of being objective and straightforward.
- Option 2: **estimated number of visits based on national data**, which would use the results of the Outdoor Recreation Valuation Tool (ORVAL), the Great Britain Tourism Survey or the Monitor Engagement with the Natural Environment (MENE) survey to calculate the number of visits made at Cashel every year. This method was used by the Scottish NCA 2020, the AECOM (2020) and by Cryle et al. (2017).

The physical flow can also be defined as the time spent on site by visitors. This can be assessed by two methods:

- Option 1: **observed time spent on site**, which calculates the overall value by multiplying the number of visits with the average duration of a visit, which is known through a survey of visitors or through an estimation by Cashel's staff.
- Option 2: **estimated time spent on site**, which uses the observed or estimated number of visits per year (see above for calculation methods) along with the average time spent on site during visits in the natural environment according to the MENE survey. This method was used by Ricardo AEA (2016).

Each definition of the physical flow allows different accounting methods for the monetary flow, either considering a value per visit or a value per time spent. We will use an estimated number of visitors provided by Cashel's trustees. We consider local data, even if estimated, as more accurate than national data. However, in the future, the collection of more precise data by Cashel's management could enable a refinement of this account. We will also use an estimation of the time spent on site during visits. Values will be provided by Cashel's trustees.

*Monetary flow account*

The monetary flow can be assessed by six different methods:

- Option 1: **valuation through travelled distance**, also called travel-cost method, includes the costs of fuel, parking and entry fees. It is recommended by the ONS.

- Option 2: **valuation through spent time**, or time-use method, considers the time spent during travel and on site, and puts a value on it using the average hour wage rate. It is recommended in the ONS/Defra principles and is used in the Scottish NCA 2020. The average hour wage rate is given by the Annual Survey of Hours and Earnings by the ONS. The formula would then be:

> *Monetary flow by time-use method = Sum on years of [Number of visits * duration of visits * average hour wage rate * (1 – discount rate)]*

- Option 3: **cost of production**: the value of all visits on site are considered equal to the costs of production of this ecosystem service, which is generally recommended by the UN SEEA when no market exists for this service. The formula would then be:

> *Monetary flow by cost of production method = Sum on years of [Costs of production * (1 – discount rate)]*

- Option 4: **fees**, which could consider admission fees at Cashel or at similar sites, or RSFS membership fees. This was used by Clark et al. 2020. However, the applicability of fees at other sites and the inclusion of other services (such as access to the RSFS journal) in the membership implies uncertainty.
- Option 5: **valuation through visited habitats**, uses results from Sen et al. (Sen et al., Economic Assessment of the Recreational Value of Ecosystems: Methodological Development and National and Local Application, Environmental and Resource Economics · February 2014) to assess the value of a visit in a certain habitat type. This method was used by Clark et al. 2020 and Dickie et al. 2019. The calculator provided by Bank of England can be used to convert 2014£ into 2021£. The formula would then be:

> *Monetary flow by visited habitats method = Sum on years of [Number of visitors * value of each visit * (1 – discount rate)]* where *Value of each visit = Sum on habitat types of [extent percentage * habitat value in 2014 * inflation conversion to 2021]* where *Inflation conversion from 2014 to 2021 = 1.14*

- Option 6: **willingness-to-pay**, which uses the results of surveys asking users how much they value their visit. This method has the advantage of assessing simultaneously recreation, aesthetics value and all other cultural ecosystem services. The formula would then be:

The use of the number of visitors to measure the physical flow leads us to exclude the time-use method. No data is available on the distance travelled by visitors to come to Cashel, which excludes using a travel-cost method. Choice was made to use the time-use method, the cost of production, the valuation through visited habitats and finally a form of willingness-to-pay (that is, donations at parking). This enables a comparison between output values.

> *Monetary flow for willingness-to-pay method = Sum on years of [Number of visitors * value of each visit * (1 – discount rate)].*

*Stock account*

There is no stock account for recreation as this ecosystem service is not limited.

---

### 2.4.5. Education

Carbon is visited for education purposes either by school trips or by the general public. Education is considered as a cultural ecosystem service and will here be assessed.

*Physical flow account*

The physical flow can either be defined as the number of educational visits made every year, or by the time spent on site during educational visits.

The number of visits should be calculated by adding:

- **Number of visits during school trips**: this can either be calculated by multiplying the number of trips by the average number of visitors per trip, or by adding the number of visitors for each trip undertaken at Cashel. The latter has the advantage of being straightforward and objective. It was used by Clark et al. (2020).
- **Number of educational visits by the general public**: Clark et al. assumed that only children made educational visits and thus accounted for children visitors among the general public. This can be done with the exact number if the data is available or with an estimation of the proportion of children among all visitors. Considering only children leads to an underestimation, but accounting for adults would expose to the risk of double-counting with the recreation valuation.

The time spent on site can be calculated by multiplying the number of visits by the average time spent on site. Each definition of the physical flow allows different accounting methods for the monetary flow, either considering a value per visit or a value per time spent.

For Cashel we will use an estimation of the number of educational visits by the general public. There has been no visit by school trips in the past few years. However, this might change in the future. The account will then have to be updated.

*Monetary flow account*

The monetary flow can be assessed by five methods:

- Option 1: **valuation through travelled distance**, also called travel-cost method, includes the costs of bus rental, fuel, parking and entry fees. It is recommended by the ONS. Dickie et al. (2019) used a variation of this method, called cost of investment, with values provided by Mourato et al. (2010.).
- Option 2: **valuation through expenditure transfer**, which is a variation of the time-use method, considers the time spent during travel and on site, and puts a value on it using the cost of an hour of education (professor wages, …). It was developped by Oras et al. (2019).
- Option 3: **cost of production**: the value of all visits on site are considered equal to the costs of production of this ecosystem service, which is generally recommended by the UN SEEA when no market exists for this service. It was developped by Oras et al. The costs could include maintenance work for educational panels, touring staff, etc. It should be underlined that there is a risk of double-counting (for example of staff expenditure) if the same method is used for recreation valuation.
- Option 4: **fees**, which could consider admission fees at Cashel or at similar sites, for educational tours if the specific value exists and for recreational tours if not. The method is recommended by the Corporate Natural Capital Accounting guidance. It was used by Clark et al. 2020.

- Option 5: **willingness-to-pay**, which uses the results of surveys asking users how much they value education possibilities at Cashel. This method was developped by Oras et al. It could lead to an underestimation since it is based on visitors' appraisal.

For Cashel there are no data on travelled distance which excludes a travel-cost method. There are no fees. Since there are no school trips, using an expenditure-transfer method is not accurate. Using an hour wage rate to value time for children is not accurate. We thus used the costs of production and the public donations (which is a form of willingness-to-pay) to calculate the monetary flow. We used the value calculated for recreation valuation.

The final formula is:

| |
|---|
| *Monetary flow = Sum on years of [Physical flow * value * (1 - discount rate)]* |

*Stock account*

There is no stock account for education as this ecosystem service is not limited.

# 3. Results

## 3.1. Stage 1 : Why ? (Risks, opportunities, relevance to decision-making)

According to the Capitals Coalition Natural Capital Protocol, the first stage in accounting for natural capital is to establish why such a process is being undertaken. A survey of the Cashel's Trustees allowed us to complete this stage.

### 3.1.1. Relation of Cashel with Natural Capital Accounting

The holding at Cashel comprises several key natural capital assets, notably woodland (native broadleaves – oak, birch, alder, hazel etc and Scots pine), peatland (blanket bog), heath and improved grassland, as well as the associated assemblages of animals and other living organisms on the land holding

The concept of natural capital therefore applies to Cashel thus:

- The ongoing and long-term management of woodland at Cashel will influence the condition of this asset and the supply of key ecosystem services (e.g. carbon, timber, recreation);
- There is scope for further land use and management change at Cashel which will influence the extent and condition of natural capital assets and the supply of key ecosystem services. Land use and management change might include further woodland creation via planting or natural regeneration (e.g. treeline or montane planting), peatland restoration, conversion of some areas of improved grassland to tourism infrastructure (e.g. car park extension, camping pods and ancillary infrastructure); and
- Changes in the extent and condition of natural capital assets at Cashel will result in changes in the provision of key ecosystem services and the private and societal benefits these deliver.

### 3.1.2. Risks and opportunities

The Cashel Board of Trustees has identified the following risks and opportunities :

- **Operational and financial** risks and opportunities, e.g. because the extent and condition of natural capital can affect the viability and profitability of timber production on the site and carbon storage / emissions from peatland (e.g. if private finance though carbon credits is sought for peatland restoration projects in the future);
- **Legal and regulatory** risk and opportunities, e.g. because the extent and condition of natural capital is a reflection of woodland design and land management decisions (e.g. planting on deep peats);
- **Societal** risk and opportunities – management of natural capital at Cashel has potential to contribute to many societal benefits (e.g. climate change mitigation, recreation, learning / education, landscape quality); and
- **Natural processes** e.g. natural regeneration of tree-line woodland on peatland may change the nature of the peatland over time. To what extent is intervention appropriate given that natural processes may lead to sub-optimal outcomes in relation to management objectives.

### 3.2.3. Impact on decision-making

The Cashel Board of Trustees evaluated the impact of this study on their decision-making as detailed below :

- Sustainable management of natural capital is implicit in sound forestry practice already undertaken at Cashel;
- A clearer understanding of impacts and dependencies on natural capital of existing and planned management operations, as well as the values associated with this could help to refine management decisions (e.g. prioritising parts of the site for further woodland expansion to achieve the greatest carbon storage benefit, understanding the relative value of different ecosystem services provided by Cashel, identifying opportunities for private investment in Cashel – e.g. via voluntary carbon markets); and
- Comparing relative natural capital values of different land use / management scenarios and outcomes.

## 3.2. Stage 2 : what ? (Objectives, selection of assessed impacts and dependencies)

Stage 1 allowed us to get started. The study continued with Stage 2, which aims at defining the objective, the scope, the impacts and the dependencies regarding the natural capital account.

### 3.2.1. Objective

The Cashel Board of Trustees formulated the objective as mentioned in the introduction (see Box 1)

### 3.2.2. Stakeholders

The stakeholders of the natural capital account were identified as:

- The Cashel Board of Trustees;
- The Cashel resident wardens;
- Other local landowners and land managers (e.g. FLS, NTS, tenanted farms);
- Local communities in the vicinity of Cashel (e.g. Drymen, Balmaha);
- RSFS;
- Wider recreational users of Cashel (e.g. walkers, runners, MTBers, wildlife watchers);
- Volunteers at Cashel;
- Downstream users of fibre and fuel (i.e. timber, other forest products) from Cashel;
- Wider public bodies (e.g. LLTNPA, SF, Stirling Council, NatureScot); and
- Private sector and potential investors in Cashel.

### 3.2.3. Scope

The spatial and temporal scope were determined by the authors of this study after a discussion with the Cashel Board of Trustees. The baseline for the assessment will be the holding in its current configuration and condition as of April 2021. The spatial scope for the assessment will be the entire holding (1,250Ha) although not all natural capital assets will be considered. The time horizon for the assessment will be 100 years, as recommended by the Scottish ONS and Defra principles paper.

The value chain boundaries were also defined: this study will be limited to activities on Cashel's site. This excludes for example upstream actors such as seeds providers.

### 3.2.4. Natural assets

The natural assets that were to be considered were selected. They include:

- forest land;
- grazing land;

- peatland;
- upland heathland; and
- water courses.

### 3.3.5. Impacts and dependencies

The impacts and dependencies, that is to say, the ecosystem services, were selected:

- carbon storage, which is both an impact (emissions from machines) and a dependency of society to natural capital (sequestration in natural habitats);
- recreation (health benefits of active visits and attributed value of passive visits), which is a dependency of both Cashel and society to natural capital;
- education, which is a dependency of both Cashel and society to natural capital;
- woodland products (timber, venison), which is both an impact (through planting) and a dependency (through harvesting) of Cashel to natural capital;
- renewable energy, which is a dependency of both Cashel and society to natural capital.

## 3.3. Stage 3 : how ? (Measurements, valuation)

Stage 2 enabled us to define the frame of this study. The next stage involves measuring changes in the state of natural capital and valuing the impacts. In this stage, as mentioned above, choice was made to implement the UN SEEA- EA method. This includes five accounts : assets extent, assets condition, ecosystem services physical flow, ecosystem services monetary flows and stocks.

### 3.3.1. Extent account

Given that this project is time-limited, it was necessary to first select the ecosystem assets that were to be considered. We here followed the indications of Cashel's trustees. The considered habitat types are thus:

- **forest land**;
- **grassland**;
- **upland heathland**; and
- **peatland**.

We will also study **water courses**. These will be considered separately, and not within one of the habitat types listed above, as they cross different ecosystems along their course.

Using Space Intelligence SLAM-MAP for NatureScot and qGIS, we were able to calculate the area of each considered ecosystem asset. We first had to allocate the habitat types listed by the map to our list of assets. The classification the assets by habitat category is described in Table 3.1 and Figure 3.1 shows the final natural capital asset map.

**Table 3.1: allocation of the EUNIS habitat types to the natural capital assets considered in this study**

| Asset | Habitat (EUNIS classification) |
|---|---|
| **Forestland** | Young woodlands |
| | Mixed deciduous and coniferous woodlands |
| | Coniferous woodlands |
| | Broadleaved and deciduous woodlands |
| | Temperate and Mediterranean-montane scrub |
| **Grassland** | Dry grasslands |
| | Mesic grasslands |
| | Seasonally wet and wet grasslands |
| | Woodland fringes and clearings and tall forb stands |
| **Heathland** | Temperate shrub heathland |
| **Peatland** | Raised and blanket bogs |
| | Valley mires, poor fens and transition mires |
| **Water courses** | Inland surface standing and running waters |

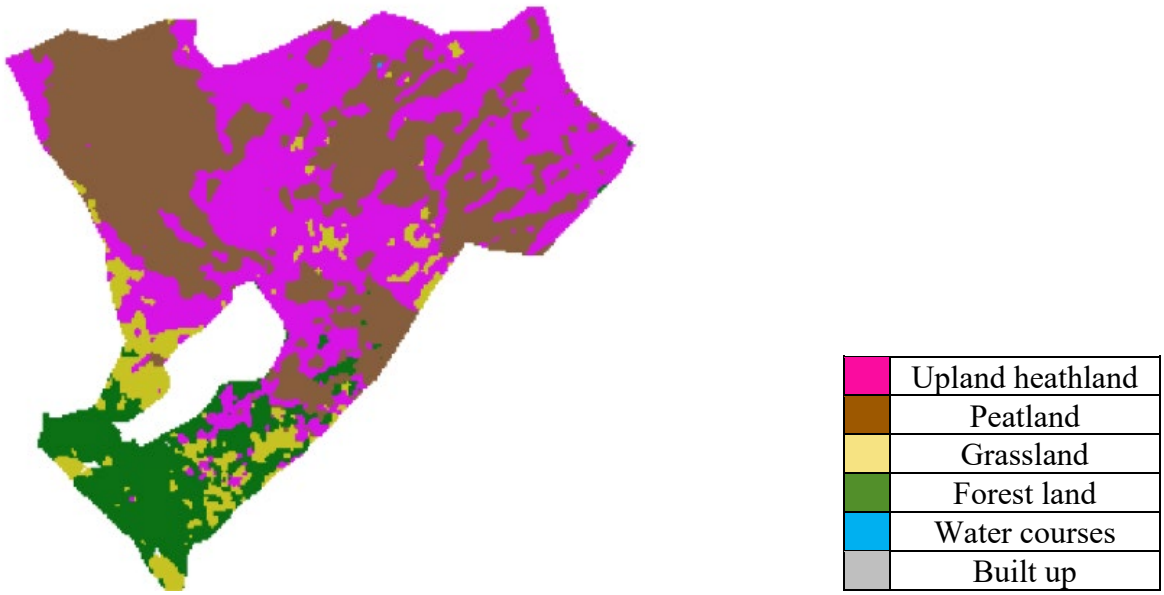


**Figure 3.1: Map of the natural capital assets on Cashel's site developed using Scotland's landcover habitat maps, released as open data by creators Space Intelligence in 2021. Full original datasets downloadable here.**

The calculated area values are presented in the table below.

**Table 3.2: extent of each habitat type and each natural capital asset**

| Asset | Habitat | Extent (ha) |
|---|---|---|
| **Forestland** | Young woodlands | 12.80 |
| | Mixed deciduous and coniferous woodlands | 0.04 |
| | Coniferous woodlands | 5.68 |
| | Broadleaved and deciduous woodlands | 116.56 |
| | Temperate and mediterranean-montane scrub | 16.48 |
| | **TOTAL** | **151.56** |
| **Grassland** | Dry grasslands | 29.56 |
| | Mesic grasslands | 8.64 |
| | Seasonally wet and wet grasslands | 35.20 |
| | Woodland fringes and clearins and tall forb stands | 15.84 |
| | **TOTAL** | **89.24** |
| **Heathland** | Temperate shrub heathland | 524.80 |
| | **TOTAL** | **524.80** |
| **Peatland** | Raised and blanket bogs | 482.60 |
| | Valley mires, poor fens and transition mires | 4.28 |
| | **TOTAL** | **486.88** |
| **Water courses** | Inland surface standing and running waters | **0.16** |
| **TOTAL** | | **1252.64** |

Hence we have the following repartition of habitat types on Cashel's site:

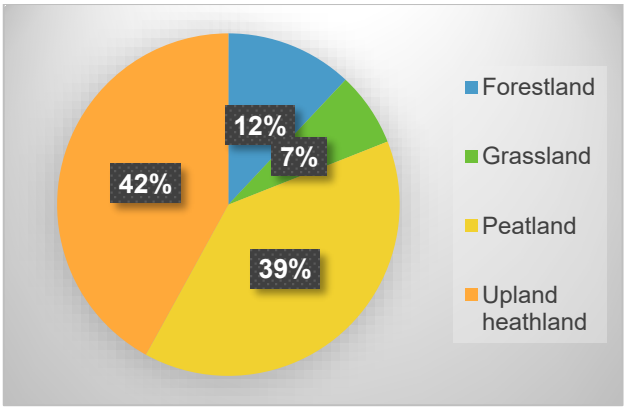


**Figure 3.2: percentage of each asset on Cashel's site**

### 3.3.2. Woodland products

#### 3.3.2.1. Timber

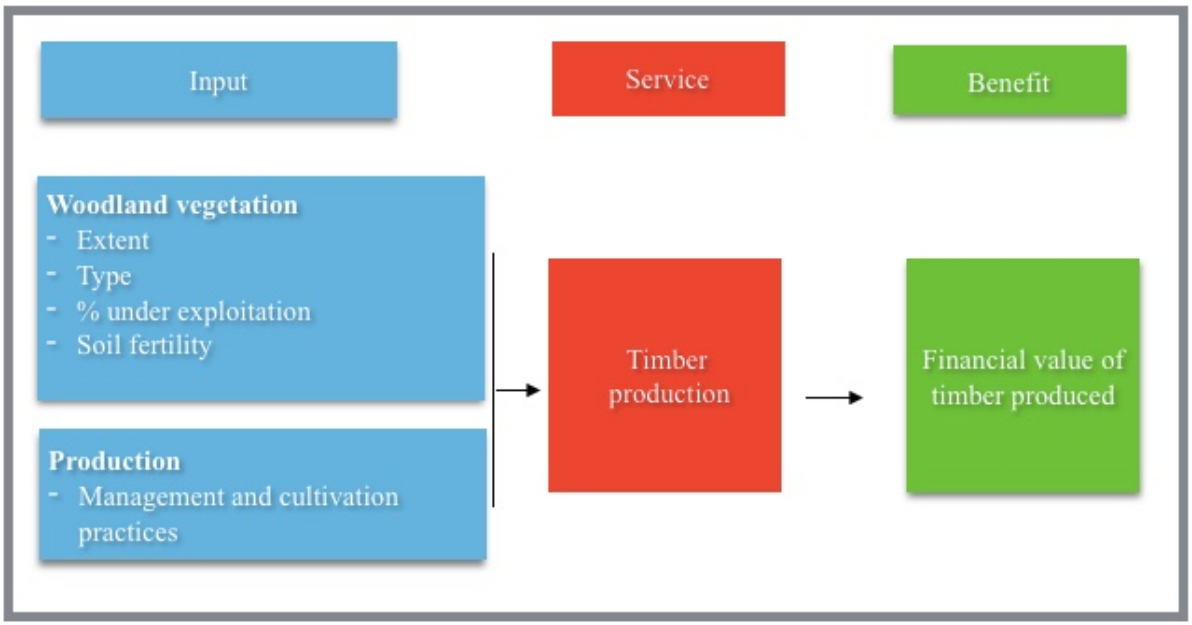


**Figure 3.3: logic chain[13] for timber production**

*Observation method*

Cashel's trustees gave the values that they expect and that we used to populate our model.

**Table 3.3: physical and monetary accounts for timber**

| Physical flow – harvest volume (tons per year) | Surplus (£ per ton) | Monetary flow (£ per year) | Monetary flow (over 100 years) |
|---|---|---|---|
| 50 | 5 | 250 | 24,000 |

#### 3.3.2.2. Venison

You will find the physical flow and the monetary flow accounts in the table below.

**Table 3.4: physical and monetary flow accounts for venison**

| Physical flow (number of killed animals per year) | Monetary flow (£ per year) | Monetary flow (over 100 years) |
|---|---|---|
| 40 | 3,000 | 291,000 |

[13] Logic chains, standardized by the eftec (see Section 2.2 in Crile et al., *A study to scope and develop urban natural capital accounts for the UK. Final report for Defra.*, eftec, 2017), are used to link the different steps of our study. They allow to show which natural assets provide which ecosystem services, but also which ecosystem services provide which societal benefits. They thus complete the UN SEEA – EA method by showing the continuity between accounts. They can also be used as a communication tool, as they allow an easy and clear visualization for non-specialists. In the following you will find a logic chain for each ecosystem service that was considered in this study.

### 3.3.3. Carbon storage

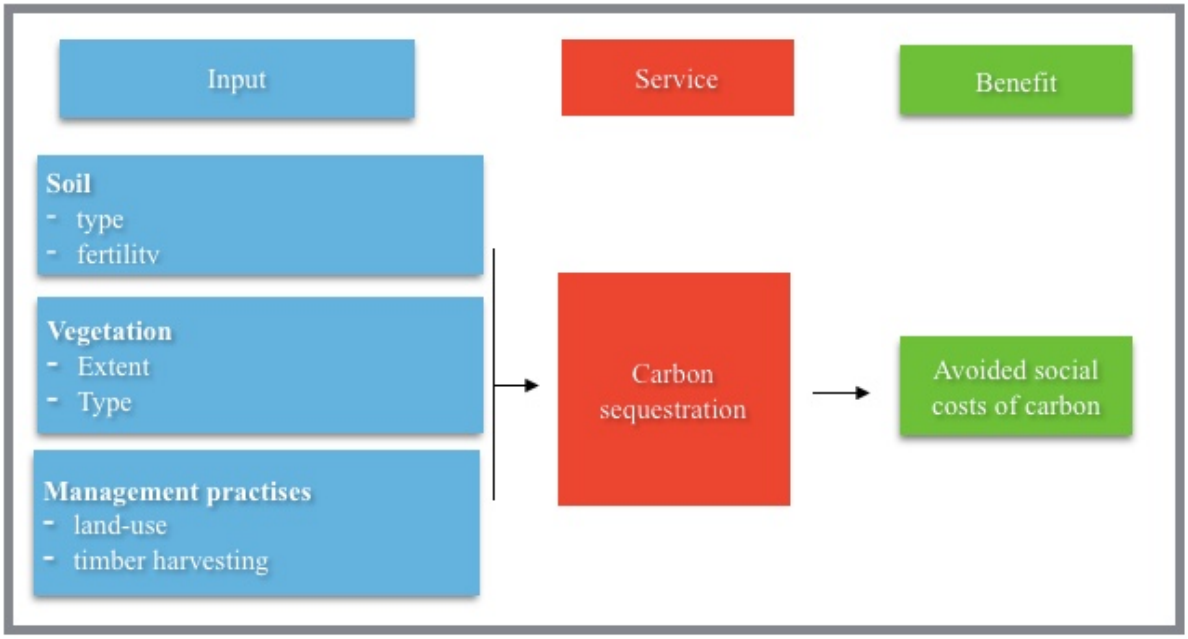


**Figure 3.4: logic chain for carbon sequestration**

*Physical flow*

We assessed emissions due to operations for ground preparation before planting:

**Table 3.5 : emissions due to ground preparation for forest planting**

| Operation | Surface (ha) | Soil carbon content (tonnes per ha) | % Soil carbon loss | Total carbon emissions (t) |
|---|---|---|---|---|
| Mounding | 312 | 1,210 | 10 | 38,000 |
| Screefing | 3 | 1,210 | 0 | 0 |

We calculated carbon sequestration by vegetation and soil for each natural capital asset.

**Table 3.6: annual carbon emissions by assets (negative values indicate Carbon sequestration)**

| Asset | Carbon emissions (tCO2 per year) |
|---|---|
| Woodland | -1,662 |
| Grassland | +151 |
| Peatland | -837 |
| Upland heathland | -1,811 |
| **Total** | **-4,159** |

We evaluated carbon emissions due to harvested products:

**Table 3.7: annual carbon emissions by harvested products**

| Harvested timber volume (tons per year) | Carbon content of harvested timber | Total (tCO2 per year) |
|---|---|---|
| 50 | 0,51 | 25,5 |

Hence Cashel site emitted 38,000 tons of carbon when planting forests but stores 4,133 tons of carbon every year.

*Monetary flow*

We calculated the associated monetary flow.

**Table 3.8: monetary flow account for carbon storage**

| Physical flow (tons of carbon) | Monetary flow (£ over 100 years) |
|---|---|
| -4,133 | 92,573,000 |

*Stock account*

As recommended by the UN SEEA – EA method, we produced a carbon stock account.

**Table 3.9: stock account for carbon storage**

| Asset | Carbon stocks (tons) |
|---|---|
| Woodland | 200,000 |
| Peatland | 589,000 |
| Grassland | 108,000 |
| Upland heathland | 612,000 |
| **Total** | 1,580,000 |

### 3.3.4. Renewable energy

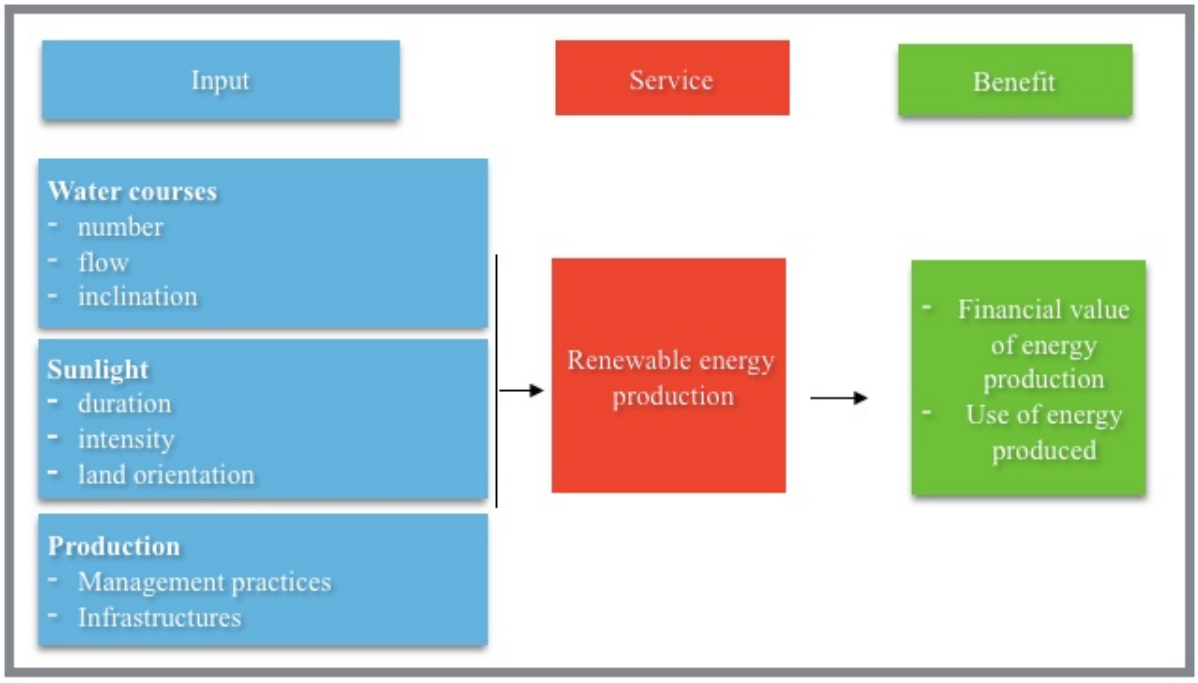


**Figure 3.5: logic chain for renewable energy production**

The Cashel Board of Trustees provided the production and income figures over the last 6 years. We thus used averages as values.

**Table 3.10: monetary flow account for renewable energy**

| Physical flow – harvest volume (kWh per year) | Monetary flow (£ per year) | Monetary flow (£ over 100 years) |
|---|---|---|
| 1,377,556 | 25,000 | 2,438,000 |

### 3.3.5. Recreation

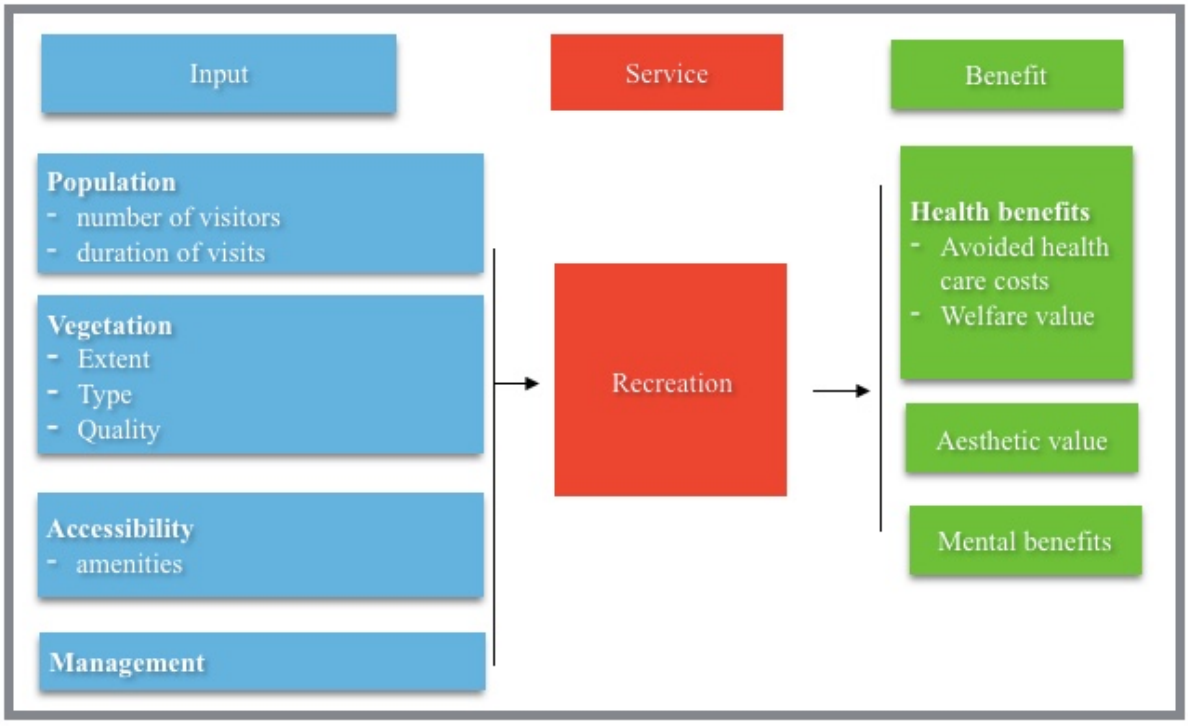


**Figure 3.6: logic chain for recreation**

#### 3.3.5.1. Health benefits

Physical flow

Cashel's trustees that about 2/3 visitors were active during their visit. We thus used 10000 as the number of active visitors.

Monetary flow

We calculated the health care costs avoided due to physical activity at Cashel.

**Table 3.11: monetary flow account for recreation (avoided health care costs)**

| Number of active visitors | Cost of inactivity (£ 2016) | Cost of inactivity (£ 2021) | Avoided health care costs due to one visit at Cashel (£ 2021) | Annual value (£) | Monetary flow over 100 years (£) |
|---|---|---|---|---|---|
| 10,000 | 29 | 32 | 0.62 | 6,000 | 600,000 |

Welfare benefits

We calculated the welfare benefits of physical activity at Cashel, that is, gained years of quality life and their value.

**Table 3.12: monetary flow account for recreation (welfare benefits)**

| Number of active visitors | QALY associated to a visit | QALY value (£ 2009) | QALY value (£ 2021) | Annual value | Monetary flow |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| 10,000 | 0.0002 | 60,000 | 82,300 | 169,000 | 16,388,000 |

### 3.3.5.2. Other cultural ecosystem services provided by recreation

Physical flow

Cashel's trustees estimate that 15000 visitors come every year on the site.

Monetary flow

*Time-use*

Cashel's trustees estimated the visits at Cashel to last in average 4 hours. We used this value to populate a time-use model.

**Table 3.13: monetary flow account for recreation (time-use)**

| Physical flow – number of visitors (per year) | Duration of each visit (hours) | Average hour wage rate (£) | Value of each visit (£) | Monetary flow (£ per year) | Monetary flow (£ over 100 years) |
|---|---|---|---|---|---|
| 15,000 | 4 | 13.68 | 54.72 | 821,00 | 79,597,000 |

*Value of visited habitats*

The average value of a visit at Cashel was calculated.

**Table 3.14: value of a visit to Cashel based on habitats**

| Habitat type | Extent percentage | Value according to Sen et al. 2014 | Value in 2021 £ | Weighed value |
|---|---|---|---|---|
| **Forest land** | 0.12 | 3.34 | 3.81 | 0.4572 |
| **Grassland** | 0.07 | 1.54 | 1.76 | 0.12 |
| **Peatland** | 0.39 | 5.03 (value for moors) | 5.73 | 2.23 |
| **Upland heathland** | 0.42 | 5.03 | 5.73 | 2.41 |
| **Total** | 1 | | **Average value for Cashel** | 5.22 |

The monetary flow was then calculated.

**Table 3.15: monetary flow account for recreation (avoided health care costs)**

| Physical flow – number of visitors (per year) | Value of each visit (£) | Monetary flow (£ per year) | Monetary flow (£ over 100 years) |
|---|---|---|---|
| 15,000 | 5.22 | 78,000 | 7,596,000 |

*Costs of production*

Costs of production were provided by Cashel's trustees. The value of each visit was calculated as the costs of production of the recreation ecosystem service divided by the number of visitors.

**Table 3.16: monetary flow account for recreation (costs of production)**

| Physical flow – number of visitors (per year) | Production costs (£ per year) | Value of each visit (£) | Monetary flow (£ per year) | Monetary flow (£ over 100 years) |
|---|---|---|---|---|
| 15,000 | 14,000 | 0.93 | 14,000 | 1,358,000 |

*Willingness-to-pay*

There are no admission fees at Cashel's site. However, there are donations for car parking. This was considered as a willingness-to-pay price.

Cashel's trustees provided an estimation of the annual donations. This was used to calculate an average value of each visit as the donations divided by the number of visitors.

**Table 3.17: monetary flow account for recreation (willingness-to-pay)**

| Physical flow – number of visitors (per year) | Donations (£ per year) | Value of each visit (£) | Monetary flow (£ per year) | Monetary flow (£ over 100 years) |
|---|---|---|---|---|
| 15,000 | 2,000 | 0.13 | 2,000 | 194,000 |

### 3.3.5.3. Comparison of all methods

Each method gives a different value for a visit on Cashel's site, as summarized in the follow table:

**Table 3.18: comparison of the value of a visit to Cashel according to different methods**

| Assessment method | Value for a visit |
|---|---|
| Avoided health care costs | £0.62 |
| Welfare | £16.90 |
| Time-use | £54.72 |
| Value of visited habitats | £5.22 |
| Production costs | £0.93 |
| Willingness-to-pay | £0.13 |

The differences can partly be explained by the calculations methods. As mentioned in the discussion (see 4.D.), we considered only some health care costs and production costs, which can lead to an underestimation.

It should be underlined that the values used for the visited habitats are based on surveys. We could thus expect the outcoming value to be close to the one calculated through the willingness-to-pay method. However, it is 10 times higher. This shows that a survey of Cashel's visitors could give interesting information on the difference between the price that visitors regard as fair and the price that visitors really are ready to pay through their donation.

We will further use the price given by the production costs method, so as to be consistent with the UN SEEA guidelines.

### 3.3.6. Education

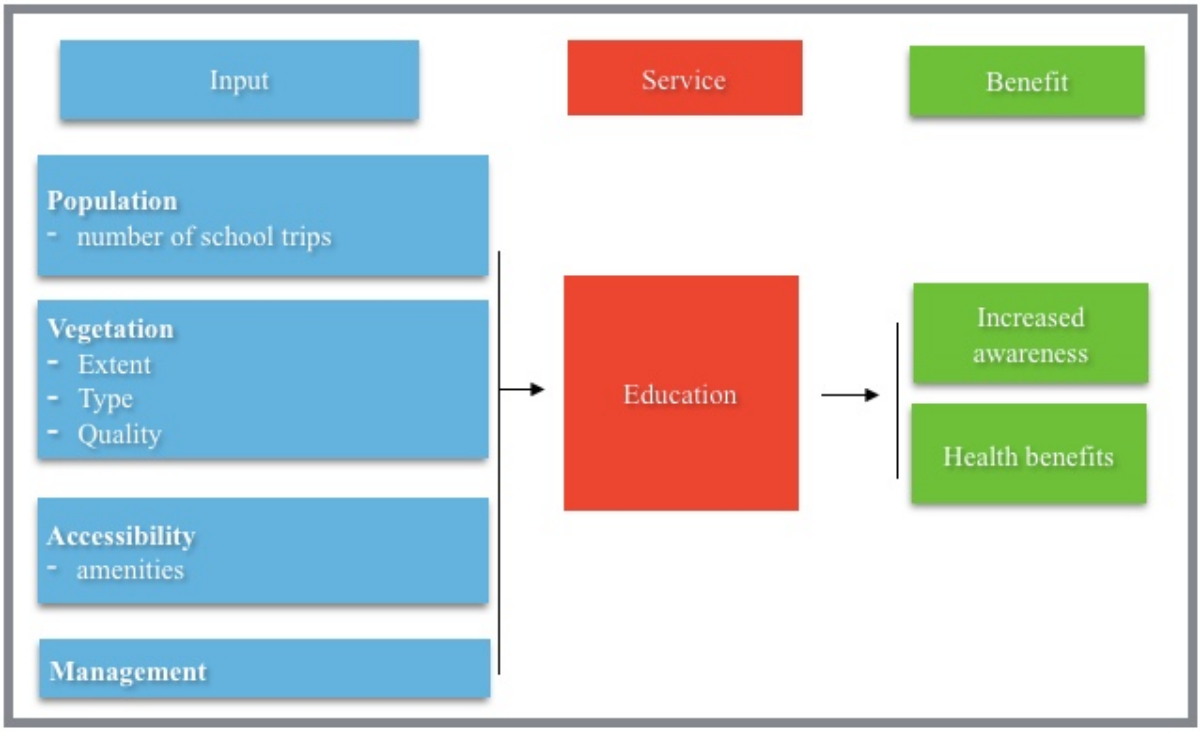


**Figure 3.7: logic chain for education**

Physical flow

Cashel's warden estimates that 25% of visitors are school-age children. As written above, it is estimated that 15,000 persons visit Cashel every year. We thus estimated the number of educational visits made by the general public to be 3,750. There are no visits made by school trips.

Monetary flow

We calculated previously the value of one visit via the production costs method and the willingness-to-pay method for recreation valuation. We will use the same values here, as the considered educational visits are made by the general public. It must be underlined that when using these methods, recreation valuation and education valuation cannot be added, as this would be double-counting.

*Costs of production*

**Table 3.9: monetary flow account for education (costs of production)**

| Physical flow – number of visitors (per year) | Value of each visit (£) | Monetary flow (£ per year) | Monetary flow (£ over 100 years) |
|---|---|---|---|
| 3,750 | 0.93 | 3,500 | 339,000 |

*Willingness-to-pay*

**Table 3.20: monetary flow account for education (willingness-to-pay)**

| Physical flow – number of visitors (per year) | Value of each visit (£) | Monetary flow (£ per year) | Monetary flow (£ over 100 years) |
|---|---|---|---|
| 3,750 | 0.13 | 500 | 48,000 |

# 4. Limitations and uncertainties

We were able to create a natural capital account for Cashel with existing data and published methodologies and hope the insights from this exercise will stimulate discussion among the Trustees about future management of Cashel. However, there are many limitations and uncertainties associated with the valuations presented in this report and recommend caution when communicating the specific values presented in this report. Below, we discuss the main limitation and uncertainties and provide recommendations for the Cashel Trustees to substantially improve the estimates in the accounts and reduce uncertainties.

## 4.1. Land cover data

The Ecosystem Extent Account (section 3.3.1) is based on the new Space Intelligence SLAM-MAP habitat map[14]. The map has not been compared to *in situ* observations in Cashel but form our limited analysis there were some surprise findings. For example, according to our calculations, there is 135 ha of forested land, while Cashel's Trustees consider that there are 246 hectares of stocked woodland. Although we could not investigate, we think this is because SLAM-MAP classified a failed Scots pine crop, where trees remain small, as heathland. The SLAMP-MAP resolution will also result in small clearings to be classified as grass or shrub habitats rather than woodland. There may be further unexpected consequences from our reclassification of the detailed SLAM-MAP habitats to the natural capital asset types used in the extent account (Table 3.1).

***Recommendation:*** While SLAMP-MAP is by far the most appropriate land cover dataset to use for the NCA, Trustees should evaluate the quality of the land cover data to understand how much it influences the accounts and whether, perhaps, local field surveys should be used to complement the earth-observation derived data for certain assets.

## 4.2. Woodland products

Cashel has not yet sold any timber, necessitating the need to use hypothetical figures for the physical flow and for the surplus. There are uncertainties in the surplus estimates because both production costs and selling prices are unknown, and the assumption that the sales volume and the surplus to be constant over time. Once a more accurate forest management plan is developed, it could be used to forecast timber revenue more accurately

For venison, we used a constant average estimated physical flow value for the next century based on Cashel's trustees estimate that 40 deer are generally killed every year. However, this could vary with the deer population and/or with public policies regarding deer population. For example, in the 2020/2021 season in which 57 red and 12 roe deer were killed. We also considered the price of the hunting lease to be constant, although it may vary in the future.

***Recommendation****:* The account could be updated with actual observed data for timber harvest and deer culls. The forest management plan can be used to forecast future timber harvests more accurately. To better align with the UN SEEA recommendation actual market prices should be used.

[14] Scotland's landcover habitat maps, released as open data by creators Space Intelligence in 2021. Full original datasets downloadable here.

### 4.3. Carbon storage

There is high uncertainty in the carbon accounts. We already mentioned the uncertainties in our extent account related to the land cover data see 4.1). Further uncertainties are added by reliance on external published estimates (e.g. for wood volume, carbon content, carbon emissions), rather than local estimates or measurements (e.g. for soil carbon or wood volume). We also considered carbon emissions to be constant over time, while these could vary with climate change and/or with land use and management. Finally, Cashel's trustees did not provide precise figures on fuel consumption and on-site grazing, so these were not considered.

***Recommendation:*** Confidence in the carbon accounts could be increased by testing the accuracy of the published estimates for Cashel and/or deriving better estimates from locally collected data. Alternative management scenarios could also be developed to explore how these would affect carbon storage.

### 4.4. Recreation and education

The accuracy of all methods used to calculate the recreation and education values is limited by the lack of precise data on visitors or active visitors, but new initiatives by Cashel to capture visitor numbers should hopefully overcome this issue in the foreseeable future. Nevertheless, assessing the value of cultural ecosystem services such as recreation and education is an active field of academic research without commonly agreed methodologies. The Scottish NCA provides a methodology, but the variation in values resulting from different methodologies illustrate that this assessment is highly uncertain.

Specific uncertainties stem from methodological assumptions and data limitations, including::

- The time-use methods rely on an arbitrary assumption of the average time spent on site and does not consider time spent traveling to and from Cashel and the average hourly wage rate used is not suitable for children
- the costs of production method included estimates for path maintenance, visitor centre cleaning and wardens, but costs for administration or insurance were not considered
- the health benefits assume that visitors that are active during their visit at Cashel and have a sufficient activity level on a regular basis to avoid health care costs and to gain quality years of life, although their real activity level is unknown.
- the willingness-to-pay method is based on an estimate of parking donations
- Also, the valuation of visited habitats rely on a study that does not provide values for every habitat type. We thus had to use the value of the closest habitat, such as moors for peatland.
- visitor numbers are considered to be constant over time, but Cashel's trustees aim at growing numbers and a growing population close to Cashel may also result in more visitors.
- The values per visit calculated for recreation are also used in the education monetary flow account, which means these values cannot be added, as this would lead to double-counting.

***Recommendation****:* Visitor surveys, planned for the summer of 2021, should include questions to improve the economic valuation of recreation, including physical activity level, the percentage of children, their travelling time and distance and the parking donations.

### 4.5. Choice of ecosystem services

Finally, many ecosystem services provided by Cashel were not considered in our accounts. These include: the biodiversity value (when considered as a cultural ecosystem service), water quality regulation, flood mitigation, pollination, and the value of Cashel for research purposes. Methods could be developed to account any ecosystem services, but one should carefully consider the merit of such analyses and the ability to meaningfully support decision-making.

# 5. Conclusion

The Natural Capital Protocol, combined with the United Nations System for Environmental Economic Assessment – Ecosystem Accounting framework provided a robust approach for the NCA. Given time constraints, it was agreed with the Cashel Trustees to focus on five natural assets (Table 5.1). Simple and more complex methods to quantify the ecosystem services for the physical flow accounts and to identify feasible valuation methods for the monetary flow accounts were identified in the literature and implemented. Table 5.2 summarises the physical and monetary flow accounts and indicates the uncertainties in a simple traffic light.

Poor data availability and substantial assumptions limit the confidence for many of the ecosystem services, but will hopefully will stimulate discussion among the Trustees about future management of Cashel. A few provisional services could be quantified and valued with more confidence, but we recommend caution when communicating the specific values presented in this report. The main limitation and uncertainties are discussed, and four recommendations are provided for the Cashel Trustees to substantially improve the estimates in the accounts and reduce uncertainties.

Natural Capital Accounting methods for rural land holdings in Scotland are in an experimental phase, and the data and methods used here have many limitations. Nevertheless, this study provides the Cashel Trustees with first insight into the value of the of ecosystem services provided by Cashel. In time, the methods and data used in this report can be improved and the accounts updated to improve accuracy of the NCA.

**Table 5.1 : Ecosystem Extent account**

| Natural asset | Extent (hectares) |
|---|---|
| Woodland | 151.56 |
| Grassland | 89.24 |
| Upland heathland | 524.80 |
| Peatland | 486.88 |
| Water courses | 0.16 |

**Table 5.2 : Physical and Monetary flow accounts**

| Ecosystem service | Physical flow (per year) | Monetary flow (over 100 years) |
|---|---|---|
| Timber | 50 tons | £24,000 |
| Venison | 40 deer | £291,000 |
| Carbon storage | 4,133 tons | £92,573,000 |
| Renewable energy | 1,377,556 kWh | £2,438,000 |
| Recreation (avoided health care costs) | 10,000 active visitors | £600,000 |
| Recreation (welfare) | 10,000 active visitors | £16,388,000 |
| Recreation (time-use) | 15,000 visitors | £79,597,000 |
| Recreation (visited habitats) | 15,000 visitors | £7,596,000 |
| Recreation (costs of production) | 15,000 visitors | £1,358,000 |
| Recreation (willingness-to-pay) | 15,000 visitors | £194,000 |
| Education (production costs) | 3,750 children | £339,000 |

# References


*Annexes to Accounting for Nature: A Natural Capital Account for the RSPB's estate in England,* RSPB, 2017

*Annual Survey of Hours and Earnings : 2020*, ONS

Clark, R., Clarke, S., Hayden, E., and Scholz, E.-M., 2020. *The Economic Benefits Supported by Land Management – A Case Study of Shapwick Heath National Nature Reserve*. Natural England Research Report NERR084.

Crile et al., *A study to scope and develop urban natural capital accounts for the UK. Final report for Defra.*, eftec, 2017

Dickie, I., Royle, D. & Neupauer, S. 2019. *Testing a natural capital approach on SNH land.* Scottish Natural Heritage Research Report No. 1144.

*Forest Sector Case Study - Applying the NCP Forest Products Sector Guide*, Project number: 60618640, AECOM, 2020

Friggens et al., *Tree planting in organic soils does not result in net carbon sequestration on decadal timescales*, Global Change Biology, Volume 26, Issue 9, September 2020, Pages 5178-5188

Glover et al., *Quantifying health impacts of government policies*, Department of Health, 2010s

*Guidelines for National GHG Inventories*, Volume 4, Chapter 12, Table 12.4, IPCC

Hanley et al., *Valuing the benefits of biodiversity in forests*, Forestry Commission, 2002

Macgaricgal et al., *FRAGSTATS : Spatial Pattern Analysis Program for Quantifying Landscape Structure*. US Department of Agriculture. August 1995

Markewitz, *Fossil fuel carbon emissions from silviculture: Impacts on net carbon sequestration in forests*, Forest Ecology and Management 236(2):153-161, 2006

Mourato et al., *Economic Analysis of Cultural Services*, UK NEA Economic Analysis Report, December 2010.

Oras et al, *Valuation of the ecosystems nature education service, valuation methods, present state and way forward, Estonia's case study,* LONDON GROUP ON ENVIRONMENTAL ACCOUNTING, 25th MEETING, 7-9 OCTOBER 2019, Central Statistics Office of Australia, session C: METHODOLOGICAL WORK SEEA EEA, SUBSESSION 15

*Physical activity fact sheet*, 2020, World Health Organization, available at: https://www.who.int/news-room/fact-sheets/detail/physical-activity

Pingoud et al., 2006 *IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use. Chapter 12 : Harvested Wood Products.*

Profft et al., *Forest management and carbon sequestration in wood products*, European journal of Forest Research, 2009

*Reviewing cultural services valuation methodology for inclusion in aggregate UK natural capital estimates. Report for Office National Statistics*. Ricard Energy & Environment. November 2016

*Scottish Natural Capital Account : 2020*, Office for National Statistics, 2020

Sen et al., *Economic Assessment of the Recreational Value of Ecosystems: Methodological Development and National and Local Application*, Environmental and Resource Economics · February 2014

Senf et al*., Canopy mortality has doubled in Europe's temperate forests over the last three decades,* Nature Communication, November 2018. (2018) 9:4978 | DOI: 10.1038/s41467-018-07539-6

Vallecillo, S; La Notte, A; Kakoulaki, G; Roberts, N; Kamberaj, J; Dottori, F; Feyen, L; Rega, C; Maes, J. *Ecosystem services accounting. Part II-Pilot accounts for crop and timber provision, global climate regulation and flood control*, EUR 29731 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-02905-2, doi:10.2760/631588, JRC116334.

Wang et al., *Measuring habitat fragmentation: An evaluation of landscape pattern metrics.* Methods in Ecology and Evolution 2014

# Appendix A: condition account

The production of a condition account was initially planned as part of this study. Possible condition indicators for each natural asset were reviewed. A table featuring the result of this work can be found below. However, the time constraints of this study did not allow us to go further.

| **Woodland** | | |
|---|---|---|
| **Dimension** | **Indicator** | **Literature reference featuring this indicators** |
| **Volume** | Timber biomass | ONS principles |
| **Biodiversity** | Number of plant species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of vertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened vertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of invertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened invertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Key specie abundance | UN SEEA 2012. Experimental Ecosystem Accounting |
| **Soil** | Soil depth | |
| | Carbon content | ONS principles |
| | Soil exposure | Vardon and Harris, *Review of ecosystem condition indicators.* Paper for the London Group, October 2017 |
| | Soil moisture | Vardon and Harris, *Review of ecosystem condition indicators.* Paper for the London Group, October 2017 |
| **Ecological condition** | Number of invasive species | ONS principles |
| **Spatial configuration** | Fragmentation | See below |
| **Access** | Length of pathways | |
| **Management** | Legal protection | ONS principles |
| | Organic management | ONS principles |
| | Sustainability of exploitation | |
| **Peatland** | | |
| **Dimension** | **Indicator** | **Literature reference featuring this indicators** |
| **Volume** | Above- and below-ground flora | ONS principles |
| **Biodiversity** | Number of plant species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of vertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened vertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of invertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened invertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Key specie abundance | UN SEEA 2012. Experimental Ecosystem Accounting |

| | | |
|---|---|---|
| **Access** | Length of pathways | |
| **Management** | Legal protection | ONS principles |
| | Organic management | ONS principles |
| | Sustainability of exploitation | |
| **Grassland** | | |
| **Dimension** | **Indicator** | **Literature reference featuring this indicators** |
| **Volume** | Above- and below-ground flora | ONS principles |
| **Biodiversity** | Number of plant species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of vertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened vertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of invertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened invertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Key specie abundance | UN SEEA 2012. Experimental Ecosystem Accounting |
| **Access** | Length of pathways | |
| **Management** | Legal protection | ONS principles |
| | Organic management | ONS principles |
| | Sustainability of exploitation | |
| **Upland heathland** | | |
| **Dimension** | **Indicator** | **Literature reference featuring this indicators** |
| **Volume** | Above- and below-ground flora | ONS principles |
| **Biodiversity** | Number of plant species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of vertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened vertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of invertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened invertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Key specie abundance | UN SEEA 2012. Experimental Ecosystem Accounting |
| **Access** | Length of pathways | |
| **Management** | Legal protection | ONS principles |
| | Organic management | ONS principles |
| | Sustainability of exploitation | |
| **Water courses** | | |
| **Dimension** | **Indicator** | **Literature reference featuring this indicators** |
| **Volume** | River flow | ONS principles |
| **Biodiversity** | Number of plant species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of vertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |

| | | |
|---|---|---|
| | Number of threatened vertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of invertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Number of threatened invertebrate species | UN SEEA 2012. Experimental Ecosystem Accounting |
| | Key specie abundance | UN SEEA 2012. Experimental Ecosystem Accounting |
| **Ecological condition** | Number of invasive species | ONS principles |
| **Spatial configuration** | Fragmentation | See below |
| **Access** | Length of pathways | |
| **Management** | Legal protection | ONS principles |
| | Organic management | ONS principles |
| | Sustainability of exploitation | |

## Fragmentation

Fragmentation is an indicator of the spatial configuration of an ecosystem. There are many methods for measuring fragmentation. We suggest using the mean core area index for the following reasons: it is classified as one of the nine best metrics for habitat fragmentation by Wand 2014; the principle is simple to understand ; it is simple to calculate. The formula is : *Mean core aera index = sum on patches of [patch core area * 100 / patch total area]*.
Core area is defined as : *Core area = Total area – edge width * perimeter.*
Hence MacGarigal wrote that « increasing edge width will decrease core area, and vice versa; therefore, the mean core area index is meaningful only if the specified edge width is relevant and meaningful to the phenomenon under investigation. In many cases, there is no empirical basis for specifying any particular edge width, and so it must be chosen somewhat arbitrarily."
We suggest using field measures to determine the value of meaningful edge width.

## Biodiversity

Biodiversity is one of the factors considered in the condition account. However it can also be regarded as a cultural ecosystem service. The Cashel's Trustees expressed the desire to value biodiversity for the Cashel's site. A method review for the valuation of biodiversity was produced :

| Valuation method | Comments | References |
|---|---|---|
| Market value – conservation auctions in Victoria, Australia | This value could hardly be used for Cashel as it is site-specific. | UN SEEA 2012. Experimental Ecosystem Accounting |
| Market value - BioBanking in New South Wales, Australia; | This value could hardly be used for Cashel as it is site-specific. | UN SEEA 2012. Experimental Ecosystem Accounting |
| Market Value - conservation banking in the United States of America | This value could hardly be used for Cashel as it is site-specific. | UN SEEA 2012. Experimental Ecosystem Accounting |
| Cost of replacement | | UN SEEA 2012. Experimental Ecosystem Accounting |

| | | |
|---|---|---|
| Damage-based estimates | Estimation of the costs for avoiding degradation | UN SEEA 2012. Experimental Ecosystem Accounting |
| Use values | Recreation and aesthetics valuation can be regarded as taking biodiversity into account. | Forest Sector Case Study - Applying the NCP Forest Products Sector Guide, AECOM, 2020 |
| Stated preference value | Price given by visitors when surveyed | Forest Sector Case Study - Applying the NCP Forest Products Sector Guide, AECOM, 2020 |
| Value of the forest for households | Average value : *Sum on forest types of [Forest extent * value of each forest type per household (according to Hanley 2002) * number of households within 500km]*. This would be an underestimation as other assets would not be considered. | Hanley et al., *Valuing the benefits of biodiversity in forests*, Forestry Commission, 2002 |
| Value of the forest for households, with a distance decay | See above. The distance decay is 20% every 100km. | *Forest Sector Case Study - Applying the NCP Forest Products Sector Guide*, AECOM, 2020 |

In the future, if choice is made to value biodiversity, special awareness should be placed on the risk of double-counting with recreation valuation.

## Appendix B: inputs from Cashel's Trustees

| DATA REQUIREMENTS | | | | SYD / SIMON FEEDBACK ON DATA REQUIREMENTS | | | |
|---|---|---|---|---|---|---|---|
| **Data / indicator** | **Unit** | **Sub-divisions (if relevant)** | **Comments** | **Data availability** | | | **Comments** |
| | | | | *Yes (expected time scale for delivery)* | *Maybe in the future* | *No* | |
| **TIMBER PRODUCTS** | | | | | | | |
| Harvested timber weight / volume | Tonnes<br>$m^3$ | • Species<br>• Product type | | None to date | Y | | Thinning of SP areas about to start in winter of 2021/22 and should continue annually thereafter. First areas will be conifer (P silvestris) though areas of birch (Betula spp) may also be thinned. Ideally some of this material will be used at Cashel for rustic timber work but, more likely, it will be used locally as firewood or, possibly, despatched as small roundwood, subject to the optimum price. Expected volume will be around 50 tonnes. Budgetted surplus is £5 per tonne giving a total anticipated timber income of around £250 pa for the next 5 years or so though this price may vary substantially depending on national and local markets |
| Market price paid for timber | £/t | • Species<br>• Product type | | | £5/t | | We have yet to test the market but would expect a surplus of around £5 per tonne |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Detailed timber production costs | £ per item | • Staff time<br>• Materials / inputs<br>- Machinery | To avoid double counting only staff time specific to timber production should be considered, hence leaving out wardens and others | | £5/t | | All timber will be sold standing ie at stump so that our costs are minimal. Only cost will be time by Ops manager for organizing sales and site information. Assume management costs are similar to timber income ie nil net income |
| Number of killed deer | No. per year | • Species<br>• Ecosystem type where dear was taken | Culling deer avoids damages to the environment, hence number of killed deer will be useful | 69 | | | 57 red and 12 roe deer culled in 20/21 season. This is substantial uplift compared to previous years so best to work on a figure of around 40 dear pa as an average. Most dear were culled on the open hill outside the woodland area. Simon has a map of cull locations for 20/21. |
| Value of the hunting lease | £ per year | | | £3000 | | | NB in Covid years (this year and last year) only 5/6 of the lease was collected to account for Covid restrictions and reduced venison price |
| Gravel extracted weight / volume | Tonnes<br>$m^3$ | | Extracted from Cashel borrow pit for use in Cashel path projects etc | 20 | | | This is based on best guestimates submitted as part of a grant application |
| Market price of gravel | £ | | | £50 | | | |
| **CARBON SEQUESTRATION** | | | | | | | |
| Operations | Ha. per year | • Type of operation<br>- Impacted area | | | | | Not sure how to answer this one! We will have management inspections (access by car); grass cutting; power tools for path construction and maintenance; tree maintenance; access for deer management; occasional wildlife surveyors. Most of this will be in the woodland area but I |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | think you can only use the whole estate area of 1253 ha as many ops relate to the whole land area. We have 246ha of stocked woodland area actively sequestering carbon along with the peat areas and other habitats (see ILMP for specific areas).<br>For fuel use I have guestimated at 1000 litres pa for management on Cahel ie excluding travel costs to Cashel for management purposes. |
| Fuel consumption | L. per year | | | 1000 | | | |
| Grazing animals | | • Specie<br>• Number | | | | | We have only deer (see above). I would guestimate that our cull is at best one-third of the population but I suspect we are culling less than that. See Integrated land Management Plan for earlier detailed estimates of deer population. There are also occasional sheep incursions onto the higher ground |
| Vegetation mass | kg per ha | • Above-ground flora dry mass<br>• Roots dry mass<br>• Wood volume<br>• Wood density | | | | | See ILMP and Long Term Forest Plan for details of habitat types which can be used for estimating these figures |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Soil carbon content | kg per ha | | There are two main measurements methods : loss-on-ignition (*LOSS-ON-IGNITION AS AN ESTIMATE OF ORGANIC MATTER AND ORGANIC CARBON IN NON-CALCAREOUS SOILS*, Ball, 1964) or elemental analyzer. | | | | Ditto |
| **RECREATION** | | | | | | | |
| Number of visitors | Per year | | | 15k-20k | | | This is best guestimate based on average of cars observed in car park and numbers of people per car |
| Number of active visitors | Per year | | An estimation (by wardens?) of the percentage of active visitors could also be used. | 10k-15k | | | Most visitors to Cashel are active ie walking |
| Parking donations | £ per year | | | £2k? | | | Simon – can you confirm? This figure has been difficult to ascertain recent years as the figure deposited has been incorp[orated into other financial info and also net of expenditure on site management materials |
| Production costs | £ per year | • Staff<br>• Paths maintenance<br>• Road work on the parking lot<br>• … | | £14k | | | We spend the following on site maintenance:<br>• £9600 pa on path maintenance; Visitor centre cleaning; visitor management by on-site wardens, as 'non-cash' services provided by our wardens in lieu of rent<br>• In 2020/21 some £4500 was spent on other aspects of on-site management |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Average travelled distance | km | | Distance from residence location to Cashel | 8320 | | | For management purposes, I would guestimate 100 miles per week pa ie 5200 miles or 8320km |
| Average time spent | min | | Addition of time spent travelling and on site | | | | |
| Willingness-to-pay admission fees | £3/car | | Price seen as fair by visitors when surveyed | | | | We have operated at this level for more than 2 years without any adverse comment. |
| **EDUCATION** | | | | | | | |
| Number of children | Per year | • Through school trips<br>• Outside school trips | For school trips, an estimation of the average number of children per school trip along with the number of school trips could also be used. Outside school trips, an estimation (by wardens?) of the percentage of children among the general public could also be used. | 4000 | | | Due to Covid we have hjad no school visits this year or last. Before that we had no organised school visits for some years now (though we have had I the past. It is our intention to start that again one visits return to normal following Covid.<br>Our warden may suggest differently but would guess on around 25% of visitors are school children age ie 4-5k pa |
| Average travelled distance | km | | Distance travelled by school trips to Cashel | | | | Best guess would be 70km round trip |
| Average time spent | | | Addition of time spent travelling and on site, by school trips | | | | Best guess would be 0.5 to 0.75 of one day |
| **RENEWABLE ENERGY** | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Amount of produced energy | kWh per year | | | | | | |
| Market price of energy | £ per kWh | | | | | | |

## Appendix C: data sources

| Account | Factor | Value | Source |
|---|---|---|---|
| **Extent** | Number of pixels | | Space Intelligence SLAM-MAP |
| **All monetary accounts** | Inflation | | Bank of England Online Inflation Calculator |
| **Woodland products** | Timber harvest volume | 50 tonnes per year | Cashel's trustees |
| | Surplus on timber sales | 5£ per tonne | Cashel's trustees |
| | Number of killed deer | 40 per year | Cashel's trustees |
| | Value of the hunting lease | 3.000£ per year | Cashel's trustees |
| **Carbon storage** | Ecological zones | | FAO Global Ecological Zones Map |
| | Above-ground biomass growth: Temperate oceanic plantation forest in Europe | 4.4 | IPCC, Vol. 4, Ch. 4, Table 4.12, 2006 |
| | Above-ground biomass growth: Boreal coniferous woodland | 1.0 | IPCC, Vol. 4, Ch. 4, Table 4.9, 2006 |
| | Above-ground biomass growth: Temperate oceanic natural forest in Europe | 2.3 | IPCC, Vol. 4, Ch. 4, Table 4.9, 2006 |
| | Below-ground to above-ground biomass ratio: Temperate oceanic forest (other broadleaf aboveground biomass < 75 tonnes ha-1) | 0.46 | IPCC, Vol. 4, Ch. 4, Table 4.4, 2006 |

| | | | |
|---|---|---|---|
| | Below-ground to above-ground biomass ratio: Boreal coniferous woodland (above-ground biomass <75 tonnes ha-1) | 0.39 | IPCC, Vol. 4, Ch. 4, Table 4.4, 2006 |
| | Below-ground to above-ground biomass ratio: Temperate oceanic forest (other broadleaf aboveground biomass >150 tonnes ha-1) | 0.24 | IPCC, Vol. 4, Ch. 4, Table 4.4, 2006 |
| | Conversion to C for above-ground biomass: Temperate and boreal - all | 0.47 | IPCC, Vol. 4, Ch. 4, Table 4.3, 2006 |
| | Conversion to C for above-ground biomass: Temperate and boreal - conifers | 0.51 | IPCC, Vol. 4, Ch. 4, Table 4.3, 2006 |
| | Conversion to C for above-ground biomass: Temperate and boreal - broadleaved | 0.48 | IPCC, Vol. 4, Ch. 4, Table 4.3, 2006 |
| | Conversion to C for above-ground biomass: Forbs and grasses | 0.45 | Friggens et al, 2020 |
| | Conversion to C for above-ground biomass: Shrubs | 0.48 | Friggens et al, 2021 |
| | Below-ground to above-ground C content ratio: Heather, birch and pine plots | 0.86 | Friggens et al, 2019 |

| | | | |
|---|---|---|---|
| | Below-ground to above-ground C content ratio: Forest land | 0.35 | Friggens et al, 2020 |
| | C content in total biomass: Grassland | 0.45 | Friggens et al, 2020 |
| | Emissions factors for soils: Temperate forest (drained organic soil) | 0.68 | IPCC, Vol. 4, Ch. 4, Table 4.6, 2006 |
| | Emissions factors for soils: Boreal/cold temperate grassland (drained organic soil) | 0.25 | IPCC, Vol. 4, Ch. 6, Table 6.3, 2006 |
| | Above-ground biomass: Cold temperate dry grassland | 6.5 | IPCC, Vol. 4, Ch. 6, Table 6.4, 2006 |
| | Above-ground biomass: Cold temperate wet grassland | 13.6 | IPCC, Vol. 4, Ch. 6, Table 6.4, 2006 |
| | Above-ground biomass: Temperate oceanic forest (Asia, Europe, broadleaf ≤ 20 y) | 30 | IPCC, Vol. 4, Ch. 4, Table 4.8, 2006 |
| | Above-ground biomass: Boreal coniferous forest (Asia, Europe > 20 y) | 40 | IPCC, Vol. 4, Ch. 4, Table 4.12, 2006 |
| | Above-ground biomass: Temperate oceanic forest (Asia, Europe, broadleaf > 20 y) | 200 | IPCC, Vol. 4, Ch. 4, Table 4.8, 2006 |

| | | | |
|---|---|---|---|
| | Soil carbon content (tonnes per hectare) | 1210 | Woodland Carbon Code |
| | Net carbon flux: Dry woodland and all types of scrub | -10.71 | |
| | Net carbon flux: Coniferous woodland | -17.51 | RSPB (2017), Table A7.1 |
| | Net carbon flux: Intact blanket bog and intact lowland raised bog | -1.7 | RSPB (2017), Table A7.1 |
| | Net carbon flux: Swamp and fen | -3.91 | RSPB (2017), Table A7.1 |
| | Net carbon flux: Dry grassland on peatsoils | 17.25 | RSPB (2017), Table A7.1 |
| | Net carbon flux: Existing wet grassland on organic soils | -6.05 | RSPB (2017), Table A7.1 |
| | Net carbon flux: Drained, vegetated upland peat | 2.73 | RSPB (2017), Table A7.1 |
| | Net carbon flux: Upland heath | -3.45 | RSPB (2017), Table A7.1 |
| | % soil carbon content losses during ground preparation operations | | Woodland Carbon Code |
| | Monetary value per tCO2 | | |
| | Habitat types extent | | Extent account |
| **Recreation** | Number of active visitors | 10000 | Cashel's trustees |
| | Cost of inactivity | 29£ per person per year | Cryle et al. (2017) |

| | | | |
|---|---|---|---|
| | QALY associated to 30 minutes of physical activity per week during 52 weeks | 0.010677 £ | Clark et al. (2020) |
| | QALY value | 60,000 £ | Department of Health (2010) |
| | Duration of a visit | 4 hours | Cashel's trustees |
| | Average hour wage rate | 13.68 £ | Annual Survey of Hours and Earnings, ONS, 2020 |
| | Value of a visit: forest land | 3.34£ | Sen et al (2014) |
| | Value of a visit: grassland | 1.54 £ | Sen et al (2014) |
| | Value of a visit: moors | 5.03£ | Sen et al (2014) |
| | Habitat types extent | | Extent account |
| | Production costs | 14,000£ per year | Cashel's trustees |
| | Donations | 2,000£ per year | Cashel's trustees |
| **Education** | Percentage of children | 25% | Cashel's trustees |
| | Value of a visit: production costs | 0.93£ | Recreation monetary flow account |
| | Value of a visit: willingness-to-pay | 0.13£ | Recreation monetary flow account |