Deliverable 2.2 - A toolkit supporting the participatory natural capital valuation framework

Project JHI-D5-1 “Bringing in participatory approaches to widen the scope of Natural Capital Valuation”

Authors: Simone Martino[1], Katy Joyce, [1]Samuel Poskitt[1], Maria Nijnik[1], Chen Wang[1], Margaret McKeen[1], Emma Coffey[2], Amanda Nystrom[1]

[1]The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8QH, UK

[2]IPT & Neurodivergency in Training at Anna Freud, 4-8 Rodney Street London N1 9JH.

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Summary

Valuing the environment involves a complex process in which interested parties discuss the values of environmental goods and ecosystem services at stake for better land use management and the achievement of human wellbeing. The classical economic valuation methods rely on the elicitation of instrumental values (i.e., value of goods assumed as means to an end for improving human welfare). However, values can be more broadly categorised to explore a range of benefits (value plurality), complementing economic benefits with relational, intrinsic and shared values by the adoption of participatory and deliberative processes to elicit individual and group values and reach informed decisions.

In this report we build on the classification of values proposed by the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) and suggest a combination of methods and tools for discussing a plurality of values to support local decision making. We initially provide considerations on typologies of values and why we need a variety of different approaches to reach value pluralism. We then describe some methods and tools that can be adopted by land users, community groups and natural capital partnerships to support decision making. These tools can be also used by researchers who want to acquire knowledge on the duality and relationships between economic and social values. To achieve this goal, we have designed several steps that support discussions on the conditions of natural capital assets and contextualise values under different scenarios through the analysis of the interactions between nature and humans.

While we recommend the full implementation of the toolset, we recognise that this can be onerous (especially in terms of time). We provide considerations on the aim and the way of implementing each of the methods proposed and briefly suggest how to use the approach at broader scale.

We are conscious that the range of methods and tools available to elicit values is wider than that proposed in this report. However, an initial pilot conducted with a number of local stakeholders working in the agricultural context and with national policy and decision-makers (Scottish Government, Nature Scot, etc.), who were shown the toolkit, revealed positive feedback on its usability, although not all the proposed methods can be easily implemented without external technical support.

Highlights

What is the report about?

This report introduces a range of methods and tools that can be implemented by practitioners to elicit, through a participatory approach, a plurality of values on natural capital and use this information for bottom-up decision making and conflict resolution.

What did we learn?

We presented several methods and tools at Glensaugh farm to members of the James Hutton institute, other private organisations managing land like Scottish Woodlands, and national stakeholders (Scottish Government, Nature Scot, Forestry Land Scotland), to show how these approaches may be operationalised. Collected feedback through questionnaire survey reported that the valuation methods proposed can be used to achieve different goals at different scales although assistance in the implementation of some methods is necessary.

What happens now?

We are continuing the elaboration of the data collected during the pilot test at Glensaugh and plan further discussions in a workshop with local and national stakeholders in the final year of the project (2026-2027). During this event, we will use the data collected and elaborated to deliberate solutions to refine our approach for the benefits of a range of decision makers such as land managers, local councils, national parks, Natural Capital Community Partnerships and Regional Land Use Partnerships.

Introduction

This document (Deliverable D2.2) describes the toolset for the implementation of the valuation framework (D2.1) developed within the project JHI-D5-1 "*Bringing in participatory methods to widen the scope of natural capital valuation*". It builds on the preliminary Milestone M2.2 that summarises the criteria adopted to select the mixed-method valuation toolset.

We propose a range of methods that supports a co-creative valuation process to capture stakeholders' values on various aspects of natural capital (NC) with the goal of supporting decision making.

Before describing the toolset, we introduce the meaning of value and then we move to the concept and approaches of valuation. In proposing a range of valuation methods, we have taken inspiration from the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES 2022) and emphasised their relevance for decision-making. We have mainly considered those features that may be of interest to practitioners in adopting the approaches proposed such as how to use them in practice, the resources necessary and what outputs we may expect from their use.

By suggesting how to implement methods and tools for NC valuation, we aim to provide insights to support local decision-making and suggestions for land use policies. In addition, we aim for this toolset to be able to stimulate future discussions with stakeholders operating at landscape scale such as the Regional Land Use Partnerships or local authorities and raise debate on the potential for extending the ideas proposed in this report to a different geographical context.

Types of value

We have developed the valuation framework (Deliverable 2.1) in alignment with the value classification proposed by IPBES (2022). Therefore, the toolset proposed in this document is designed to comply with this value setting.

Because our valuation approach aims to understand and inform socio-ecological systems (Sarkki et al., 2017) by co-creating knowledge with a range of stakeholders, it is essential that it captures broad values that describe human-nature relationships. Analysis of stakeholders' values must reflect individualistic and collectivistic perspectives (preferences) of society (Kenter et al., 2016b) to fully capture the total social value (Burdon et al., 2019), a measure of the ecological and socio-cultural preferences beyond the more conventionally acknowledged economic benefits. Pascual et al. (2023) recognise that values are complex and can be widely classified looking at different intertwined aspects that include:

- *worldviews* - the ways in which people conceive and interact with the world. These can be considered as bodies of knowledge, practices, and beliefs such as academic, indigenous, and local knowledge systems;
- *broad values* - the moral principles and life goals that guide people-nature interactions;
- *specific (contextual) values* - judgements regarding the importance of nature in particular contexts, grouped into:
    - instrumental values (i.e., representing a means to a desired end often associated with the notion of Ecosystem Service [ES]);
    - relational values (i.e., representing the meaningfulness of human-nature interactions);
    - intrinsic values (i.e., representing the value of nature, independent of people);
- *value indicators* - the quantitative measures and qualitative descriptors used to denote nature's importance in terms of biophysical, monetary, or socio-cultural metrics.

Assessing multiple values is important to consider a more balanced range of views in decision making. This may reduce the dominance of those values that mostly relate to materialism and emanate from a market-based utilitarian view, whilst mobilizing relational, intrinsic, and non-market instrumental perspectives (Kenter et al., 2016a; Kenter, 201a; de Valck et al., 2023). In addition, considering broad values as an overarching or umbrella concept helps address how societal goals are aligned with general principles like justice, stewardship, sense of unity (oneness), and responsibility towards other people and nature (Kenter, 2016; Kenter et al., 2016a; Sarkki et al., 2019a).

Following Vatn et al (2024), we aim to discover a range of values through discursive power (e.g., the influential capacity of narrative), and which ones may become predominant, challenging the status quo value-system and reframing the rules chosen for the management of natural resources. These values propose a less utilitarian oriented vision of nature towards an eco-centric or biocentric view, more aligned to the proposition of conservationists, that embeds intrinsic values of nature (i.e. unrelated to the benefits generated for humans) (Himes et al., 2024).

Classification of valuation approaches

Valuation can be considered the act of eliciting individuals' and groups' preferences on principles informing day-to-day rules adopted in decision making. Thus, valuation becomes the process of building values for a better decision-making process to generate impacts on ecosystems and influence human wellbeing.

A fit-for-purpose approach does not exist, but multiple valuation avenues are available according to the aim of the valuation process. Some forms of valuation may be more adequate for extracting values of nature unrelated to the contribution they provide to people. These valuations mainly consider ecological functions and processes, not the relationships between natural and human dimensions. Other approaches to valuation may be more aligned to an anthropocentric perspective of what is relevant to an individual or a community and are based on the exploration of uses, non-uses and relational values between humans and NC (Himes et al., 2024) through a combination of stated (i.e., declared) or revealed preferences (i.e., based on the observation of human behaviour).

While valuation methods are numerous and a comprehensive description of approaches can be found in Kenter et al (2023), we use, for this report, the classification proposed by the IPBES (Termansen et al., 2022) that offers an approach to discover stakeholders' lexicographic preferences. This combination of values needs to:

- be based on scientific and deliberative methods,
- consider human behaviour in scenario management,
- integrate participatory approaches into NC valuation (Nijnik et al., 2011; Burdon and Potts, 2020),
- facilitate feedback in policy formulation.

It can be elicited considering three sets of approaches (Termansen et al., 2022):

1) sources of information generated by the environment (*nature-based valuation methods*);
2) analysis of people's behaviour (*revealed and stated preferences approaches*);
3) assimilation of valuation approaches to decision making (*integrated valuation*).

Nature-based valuation methods

Within this category we consider approaches that generate information about the intrinsic importance of nature, providing knowledge of its biophysical properties such as species diversity, biodiversity hotspots and threatened species (Swart et al., 2001), ecosystem structures and processes underpinning NC assets (Bateman et al., 2024). Common methods refer to the direct measurement of environmental variables, and modelling of ecosystem processes. Spatial analysis often accompanies these approaches to map the resources modelled or inventoried. These methods are quantitatively informed by natural sciences.

Stated based valuation methods

These approaches ask people to state their preferences verbally or in writing, thus generating information directly from participants (Tinch et al., 2019). They are commonly used to elicit utilitarian values that quantify and qualify people's interaction with nature, nature's contribution to people (Pasqual et al., 2023) and nature-derived wellbeing (Diaz et al., 2015). Utilitarian values can be also monetised, eliciting people's willingness to pay to obtain the benefits of the services provided by nature conservation.

Stated preference approaches are usually implemented through an individual-based valuation strategy assuming pre-formed preferences. However, elicitation of monetary and non-monetary values of nature can be achieved through a mediated process where knowledge is endogenously co-created through interaction between participants and a facilitator to encourage contribution from all participants and the emergence of shared value judgements (Kenter, 2017). A wide range of values can be captured, from individual utility-based values, expressed under neoclassical utility maximization assumptions (Christie et al., 2012; 2019), to intrinsic values of nature (such as bequest and existence values), building on non-utilitarian stances (Hirons et al., 2016).

Revealed based valuation methods

These approaches are based on the observation of the behaviour of individuals to quantify the value of nature's contribution to people (Bockstael & McConnell 1993). They can be operationalised by economic and non-economic methods.

Economic methods refer to approaches that link the characteristics of the environment to market goods (Hanley and Barbier, 2009). From the analysis of these markets, it is possible to infer, for instance, recreational benefits by travel cost method (Perman et al. 2003), or the values of natural amenities (quality of a landscape) or negative externalities such as noise and pollution observing at property markets by adopting the hedonic price method (Pandit et al., 2014; Casola et al., 2022).

Revealed based valuation approaches that use non-monetary indicators are also emerging. They examine documents, texts, images (Scholte et al., 2015), photos posted in social media (Mancini et al., 2018), as a proxy to obtain recreation and ecotourism value.

Integrated approaches to valuation

Some approaches operate by synthesising different types of information and integrating inputs from different methods and a plurality of stakeholders. The integration involves two main aspects (Termansen et al., 2022):

- the way in which the value is formed;
- the way in which information is used to support decision making.

Examples of the first category refer to participatory mapping that can be used to identify nature's contribution to people according to stakeholders' knowledge (Brown and Fagerholm, 2015), or to the modalities of connecting natural and social systems (Kellert, 2012). Examples of the second category refer to cost benefit analysis (Hanley and Spash, 1996), when dealing with environmental benefits and costs that can be aggregated in monetary units; multicriteria decision aid, to deal with multiple and conflicting objectives valued by stakeholders under a range of criteria (De Castro Pardo et al., 2020); and deliberative decision making processes, in which group level consensus is pursued through discussion (Martino and Kenter, 2023).

The challenge of these methods is to take account of various stakeholders' interests in the valuation process and provide information to decision-making based on multiple values (Termansen et al., 2022).

Approaches adopted in social and economic valuation

Table 1 proposes a list of economic, social and participatory methods to facilitate discussion groups, knowledge co-creation and consensus building. These approaches focus on analytical and deliberative ways of eliciting values and do not consider methods coming from the domain of natural sciences. This list is not exhaustive and focuses on social and economic methods and approaches based on deliberative analysis.

Table 1: Examples of methods and tools suitable for the implementation of the Framework -adapted from Nijnik and Miller (2017), Eastwood et al., (2013) and Kenter et al. (2023).

Methods and techniques		**Description**
Economic	Stated preference methods	Participants are asked in surveys to express their willingness to pay for different aspects of nature that provide a cultural benefit (e.g., heritage value or place). The most common approaches are contingent valuation and choice experiments.
	Revealed preference methods	Participant behaviour is observed and captured in a database or revealed through survey. Choices made in markets through the "invisible hand" of price and transactions of tangible assets such as land, properties, hunting licences, etc may be used to indirectly attribute value to environmental goods and services associated with the object of the market.
	Benefit transfer	This approach is used to transfer economic values from the study to the policy site under the assumption of social, economic and environmental similarities. Implementation based on single data transfer or function approach is possible. It is also possible to link this approach to NC accounting valuation, formulated at national scale. Transferring national values of ES to a local context may introduce incorrectness in the valuation process, but it remains a simple way to show changes of land use that can be deliberated in further discussions.
Deliberative	In-depth discussion groups	Group discussions (often repeated and usually involving four to eight people) are adopted to develop themes in ways relevant to their own needs and priorities.
	Focus group	Focus groups are interviews of a small group of stakeholders who share similar characteristics and interests. They can be used to discuss and elicit a range of broad and contextual values. The valuation process is generally facilitated to achieve a group-based valuation. In addition, the discussion may facilitate the emergence of values which may be difficult to elaborate for an individual lacking specific knowledge.
	Scenario planning	Discussions in groups facilitated by an experienced evaluator may be used to help stakeholders prepare for uncertainty and make informed decisions under different contexts shaped by a range of drivers (social, economic, political, environmental, etc.). This involves identifying potential scenarios, imagining their outcomes, and developing strategies to navigate changes.

Methods and techniques		Description
Interpretive-deliberative	Participatory mapping/GIS	A group of stakeholders considers or creates a physical or digital map to indicate landscape features that are valuable (and/or problematic). Participants may also rate or rank these features for importance. Map layers can also incorporate photo, video, artwork, poetry, etc.
	Photo-elicitation	Storytelling and photo elicitation are adopted asking participants to tell stories and provide comments around photos about their experiences of or in relation to places. These may be reflected upon in a group setting to discuss values related to these experiences.
Psychometric–deliberative	Q-methodology	A method that organises qualitative statements that are evaluated and prioritised (ranked and sorted) by respondents. These are then analysed statistically by multiple regression and principal component analysis (PCA) to look for variations across individuals' values (views) and identify (cluster) and explain prevalent values (views) that exist through a discourse analysis.

Selection of methods for co-creation analysis

There is no ideal method and therefore we recognise that a valuation must be based on a range of approaches able to elicit a plurality of cultural, shared, and social values (Miller et al., 2009; Nijnik et al., 2017; Kenter, 2016; Turner et al., 2019) that can be compared with the more traditionally explored monetary aspects associated with NC (Kenter et al. 2016a). Integration of approaches is necessary to avoid the risk of a methodological divide in which conventional economic valuation techniques deal with utilitarian and productive services, whilst deliberative and participatory methods deal with shared social and cultural values, in isolation from each other (Kenter et al. 2016b).

We make use of interpretive-deliberative methods that link deliberation with qualitative analysis of a range of values unexplored by economics. **GIS participatory mapping** (Burdon et al., 2019) is a flexible and adaptive approach that has the potential to facilitate the valuation of place-based NC assets (Burdon et al., 2022) through the emergence of social, relational and utilitarian values. It can be used to set the scene for understanding the nexus between ecology and economics. Effective NC valuation would require not only expert facilitation, but appropriate information technology (IT) to capture and communicate results (Burdon et al., 2019; Miller et al., 2006). NC valuation has fundamentally changed with the provision of mapping services, including 2D, 3D models and virtual reality (Wang et al., 2016; Nijnik and Miller, 2017; Nijnik et al., 2011; Nijnik et al., 2013). These visualization methods are particularly suitable for facilitating engagement with and knowledge dissemination between policy makers, stakeholders and the public, and reducing controversies in the implementation of conflicting scenarios (Miller et al, 2009).

The deliberation of contextual value may benefit from the production of a narrative through **scenario planning.** Under this approach stakeholders may deliberate changes in NC considering different trends of drivers relating to technical, social, economic, environmental and political aspects of our society. A benefit of this approach is to think in terms of visions rather than forecasts that can be used to address national policies or adapt and mitigate to climate change locally.

Deliberative-psychometric approaches include amongst others **Q method** to systematise stakeholders' viewpoints on value (Kenter and O'Connor, 2022) and investigate the perspectives of participants informed by different value stances (from utilitarian to eco-centric perspectives) (Nijnik et al., 2011; 2013). The Q-method can be used to classify different values or preferred management strategies to categorise stakeholders according to their choices to reveal competing agendas and provide ideas on how to reduce potential conflicts. The approach is suitable for reducing information, systematising points of view and revealing patterns between participant attitudes across a sample of variables. The goal is to capture the breadth of perspectives involving the analysis of approaches used to manage NC.

Deliberation through **photo-elicitation** is a useful method for eliciting data on the relational and cultural values held by individuals with nature in their local environments and for providing channels for local participation in decision-making. This method encourages participants' reflection on local 'place', with the aim of understanding experiences of environmental change and for capturing policy or land management preferences related to local environments, for example.

Assessing **biophysical and economic values of ES** under different scenarios by transferring benefits from other similar contexts or from national accounts can be a viable strategy to reduce the cost of collecting data by stated or revealed preferences methods (UN, 2021). We support the interaction with tools supporting the rapid assessment of biophysical and economic values of ES such as the Natural Capital Tool under development by Nature Scot. We recognise that the use of stated preference approaches (such as Contingent Valuation Method) might provide explicit values and would be relevant for the analysis of amenities or aesthetic values of the landscape.

Finally, **deliberation** as a process to agreeing on a plurality of values by consensus or majority vote can be considered when values are poorly formed around complex environmental questions but which when well-designed can gather complex contextual perspectives (Kenter et al., 2016a, b).

The valuation framework

The Framework depicted in Figure 1 is designed to facilitate the integration between the approaches and tools mentioned in the previous section and to avoid the risk of a methodological divide between conventional economic valuation techniques designed to elicit utilitarian and productive goods or services, and deliberative and participatory methods, dealing with shared social and cultural preferences (Kenter et al. 2016b).

While we recognise that the approach proposed is modular, and each element of this framework can be applied independently, we recommend following the regular flow of actions reported in Figure 1. The first step of the approach consists of a preliminary analysis of the importance of different values and how these can be classified using the IPBES framework (2022) to fulfil societal and individual needs. For the aim of the JHI-D5-1 project, this first step was exemplified by gathering experts and stakeholders' opinions on forest and woodland values and their perceptions of climatic risks on forest-based NC (Joyce et al. 2023a; Joyce et al. 2023b). This part of the framework can be used to emphasise the goals that motivate the valuation of nature for decision making: 1) the protection of nature as a goal in itself; 2) the support of nature as a means to generate human well-being; and 3) the management of nature to achieve justice outcomes (Vatn et al., 2024).

Discussing NC values under different drivers (social, economic, environmental, technical and policy-related) supports the formulation of alternative scenario narratives that can be contextualised to elicit a range of perspectives. Here we refer to the utilitarian perspective of nature captured through the economic analysis of individual preferences as willingness to pay to produce services as an end for human welfare. But also to the possibility of recognising a plurality of values that are incommensurable, not substitutable and not comparable across metrics. The analysis of multiple values can be done under different scenarios that can be compared against the status quo.

Finally, deliberation can be used to discuss win-win solutions or ways of overcoming conflicts by recognising that instrumental and anthropocentric preferences of managing NC are not dominant anymore in a society expressing value pluralism (Pascual et al., 2023). Details on the theory of these approaches and their choice can be found in Deliverable 2.1 (Martino et al., 2024). In the following sections we describe how these different approaches can be implemented, emphasising the resources needed and providing where possible examples and our experience developed in the JHI-D5-1 project.

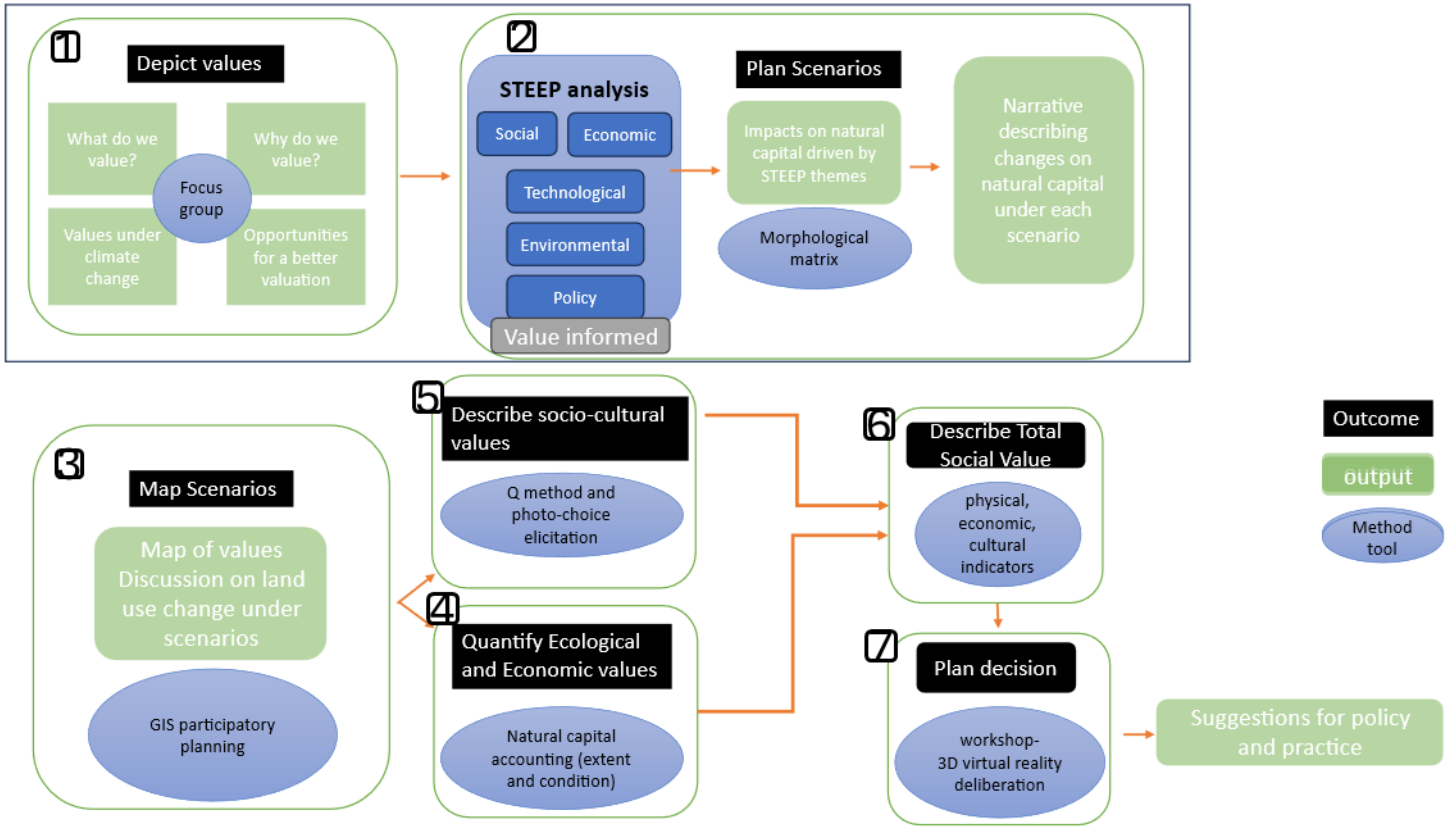

Figure 1: Valuation framework developed in the project and methos selected for its implementation at Glensaugh farm

The upper part of the framework addresses the issues of what values *are* and how these values (box 1) can be used to discuss, under different drivers (social, technology, economy, environment, and policy), future scenarios for the NC of interest (for instance a forest or peatland) (box 2). The discussion around the change in NC under different scenarios is mediated by the set of values expressed in the valuation exercise (box 1). Approaches in box 2 can be used for the formulation of a new policy and to set a range of scenarios for resource management that reflects the values a society is expected to generate from the implementation of that policy. The bottom part of Figure 1 proposes a strategy to contextualise the scenarios emerging from the policy discussion and to measure, by a participatory GIS mapping approach (box 3), a range of values referring to the environmental, economic, and socio-cultural domains. Economic valuation (box 4) can be implemented to assess the benefits to society of certain decisions and can be used for policy appraisal (e.g. cost benefit analysis). Additional analysis, based on the NC accounting framework, can be used to get a sense of strong sustainability, exploring over space, and if possible, over time, the change in the stock of resources and the flows of the ES generated. Finally, the socio-cultural values (box 5) reflect the capacity of individuals to relate with the environment and show non-utilitarian perspectives. The three typologies of ecological, cultural, and economic values (box 6) form the Total Social Value (TSV). A dashboard of indicators can be used to describe the TSV under different scenarios and to analyse potential trade-offs. To reduce conflicts between stakeholders (in other terms trade-offs may emerge), it is recommended to have a final discussion based on deliberation over contested issues (box 7) to decide on strategies that reduce the level of conflicts and generate the highest degree of satisfaction amongst stakeholders.

How to use the manual

This section describes how to implement a range of methods and tools to support stakeholders in the assessment and valuation of NC within the landscape in which they operate and support decision making. The description of each method is a clear logical step to support the implementation of the valuation framework.

The process can be divided in 7 steps, reflecting the range of activities described in the valuation framework. These 7 steps can be implemented individually, and in sequence in which the output of an approach can be used as an input for the following process. Each approach contributes to generating a specific aspect in the valuation of NC, but when considered as a unique process they all contribute to facilitating decision making. These steps are:

1. Exploring a plurality of values
2. Participatory Scenario Planning
3. Mapping values
4. Exploring and categorising stakeholders' perspectives
5. Deliberating on socio-cultural values
6. Quantifying ecological and economic values
7. Planning decision by deliberation on the total social value

The following sections of this document are designed to provide the information necessary to implement each of the steps listed above. While having experience of the concept of value and valuation can be an important asset to get the best from the implementation of our approach, this is not an essential condition. The seven guiding steps can be implemented by those who do not have strong experience with values and valuation. The main recommendation is to become familiar with the materials necessary to implement each step, and to remember that the success of the valuation process is centred on hearing people. It is important to be friendly, honest and respectful of participants' ideas and culture, limiting dominant voices, managing time well and keeping participants well engaged.

Each step is described in a simple way, focussing on the justification of its use and how it can be practically implemented. For additional information on the theory, methodological reasons behind each approach, and examples, the reader may consult the key references proposed.

Step 1- Exploring a plurality of values

Goal of the method

Eliciting values is the process of uncovering and understanding the core principles that guide a person's decisions, motivations, and behaviours. To do this, it is necessary to investigate, through reflective questioning, what truly matters to someone in different aspects of life. This goal can be pursued by carrying out interviews, questionnaire surveys or focus groups, or through observing people's behaviours by implementing revealed preferences methods. Here we focus on the possibility of exploring preferences through focus groups to facilitate a discussion on a range of values. These values may refer to overarching principles (umbrella values that inform our life); shared norms that are commonly accepted by a community (society); and other contextual values relevant in day-to-day life.

What is it?

Focus groups are qualitative group-based interviews organised by researchers to understand opinions, attitudes, and perceptions about a product, service, or concept.

How is it implemented?

The approach is implemented by formulating questions to the group in either structured (i.e. more closely led by the researcher) or unstructured (i.e. the researcher sits back more) format. Unstructured focus groups typically require more planning in advance. Focus groups are commonly held in-person but can also occur online.

In the JHI-D5-1 project we have used this approach to explore four items related to forest and woodland values (Joyce et al., 2023a, b): 1) What do we value? 2) Why do we value? 3) How are values seen under climate change? 4) What are opportunities for a better valuation? Stakeholders were split according to their will and interest into two groups, one discussing valuation, the other, climate change risk and mitigation strategies. The two breakout sessions were facilitated using a virtual board for participants to report their ideas as single keywords, messages, etc., that were discussed and commented upon following some prompts prepared by the facilitators before the meeting. The discussions emerging from the focus groups were recorded and then transcribed (although summaries of group discussions can be written up instead) and then coded (i.e. using NVivo or similar software).

What output does it generate?

Focus group outputs can range from participant responses to policies through to lists of collective values, for example. In the JHI-D5-1 project we used thematic analysis, which identifies recurring themes and organises them into meaningful categories, to extract insights on what values entail for different stakeholders. We found a limited integration, in practice, of cultural values, but we positively observed that the forestry industry is open to implementing plans that are not only based on the mere economic value of timber but consider multiple functionalities of forest in order to respond to the effects of climate change (Joyce et al., 2023a). Results can be summarised by aggregating and categorising the range of opinion provided. For instance, under the theme "what do we value about forests" stakeholders used an electronic board to show their opinions, as proposed in Figure 2.

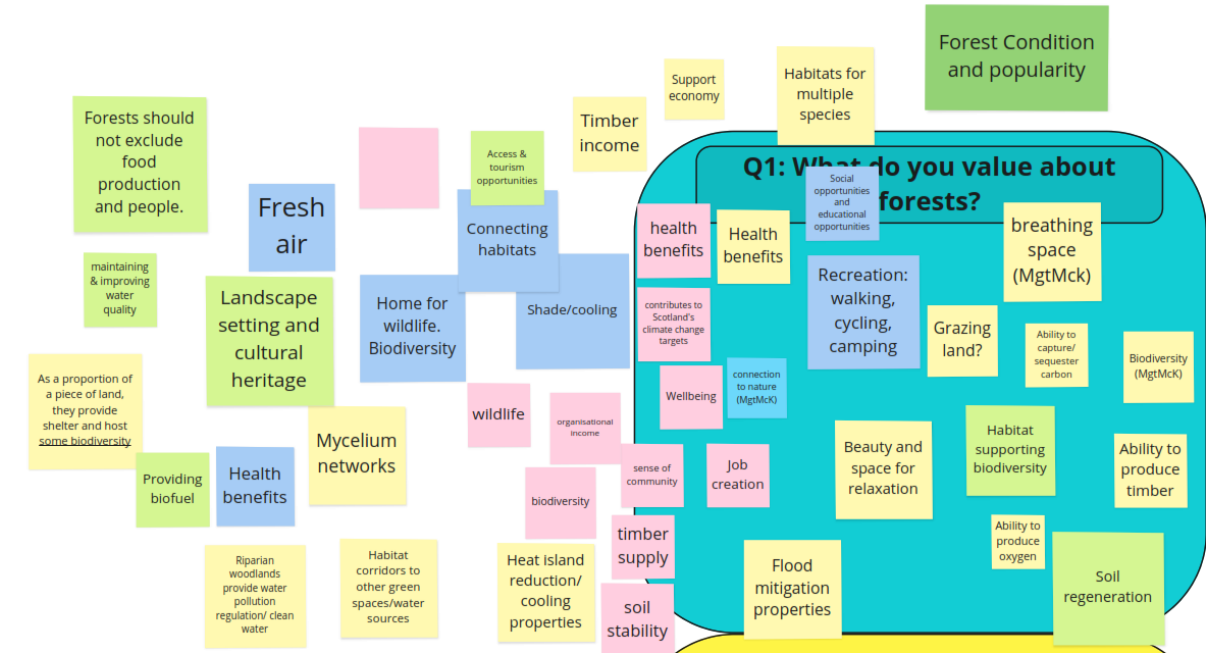

Figure 2: List of all the values reported by stakeholders for forestry and woodland. Source (Joyce et al., 2023a).

What resources are necessary?

Focus groups are a relatively low-cost and convenient approach to collecting information and are not very time-consuming in comparison to other qualitative (e.g., ethnographic) participatory methods. Organisational skills, capacity and budget are needed to arrange meetings, book suitable venues, catering, researcher accommodation and subsistence payments, and to recruit participants and pay for their time (if payment is being made). Skilful group facilitation practices are needed to enable participants to feel comfortable and safe talking together (Kitzinger and Barbour, 1999). Information can be summarised in flipcharts, using physical *post-it* notes, but for those operating online, an electronic board can be used (as in Figure 2). There are free versions operating under the most used operating systems such as Mural, and others which have a greater range of functionality such as Miro that can operate with or without licence. For in-person focus groups a dictaphone is often used to generate audio-recording. Video recording can be also used when the event is virtual. Experience in using coding software such as Nvivo for analysis, or alternative open source software offering similar functionalities such as QualCoder, TaGUETTE and MAXQDA is of added value for facilitating the analysis. As an alternative, for a high level and rapid analysis, coding and thematic investigation can be based on notes and summaries simply using Word tables or Excel spreadsheets.

Step 2- Participatory Scenario Planning

Goal

The goal of scenario planning, in this toolset, is to use narrative descriptions of the future (scenarios) to explore plausible future social, economic, environmental, policy, and technological conditions that could affect the management and use of NC. In so doing, this method can support processes of understanding and evaluating NC in the following ways, to:

- Explore the future development of trends that influence how NC is perceived, valued, managed and used (Saito et al. 2019; Weh et al., 2023).
- Bring in different types of knowledge about NC from a range of different stakeholders and stimulate discussion about the different ways in which people know and relate to nature (Poskitt et al., 2021; Butler et al., 2020).
- Support planning and decision-making for the management and use of NC by considering responses to a range of future possibilities (Capitani et al., 2019).

What is it?

Participatory Scenario Planning (PSP) involves groups of people collectively imagining, developing and analysing narrative descriptions (scenarios) of future conditions in relation to a particular subject (Bennet et al., 2016). In this case, the subject is NC and how it is managed and used. PSP is generally not considered as predicting the future, but rather building scenarios based on things that could, plausibly, happen in the future. Scenarios may cover a range of future timeframes, but in piloting this toolset, we focused on scenarios for 2045, which is the Scottish Government's target for meeting 'net zero'.

How is it implemented?

PSP is a creative and flexible practice that may be implemented in a multitude of different ways. The approach suggested in this toolset is just one way of doing things and may be adapted, depending on specific contexts. Our approach is primarily explorative but also explicitly asks participants to make value judgements about positive and negative future developments and trade-offs. We have developed a set of scenarios that describe future social, technological, environmental, economic and policy conditions related to NC in Scotland up to 2045. We developed the scenarios, together with a group of 13 stakeholders, including researchers, policymakers, land managers, and representatives of rural communities in January – February 2024. We held a workshop in January 2024, in which we brought these stakeholders together to explore their perspectives on futures for NC. This scenario development workshop contained the following elements:

- Overview of the framework for NC valuation (see p.13-14) and explanation of how to use it to consider a range of different types of human-nature relationships in building the scenarios.
- A timeline activity, in which groups of participants were asked to identify events, changes and trends that have influenced NC in Scotland, over the past 15 years, and then events, changes and trends that could influence it over the next 20 years to 2045.
- A STEEP analysis (Duckett et al., 2022), in which groups of participants were tasked with identifying the Social, Technological, Environmental, Economic, and Policy drivers that influence NC in Scotland, based on their timelines.

- A Morphological Matrix (Ritchey, 2011), in which each group of participants was asked to select two drivers from each of the STEEP categories, and then derive positive, negative and 'business as usual' assumptions about how each driver could develop up to 2045. Participants then added these assumptions to a matrix, with each matrix cell containing an assumption about a particular driver.

The researchers then took the matrices from each of the three groups and used combinations of the assumptions therein to develop narrative descriptions of the future, containing positive, negative and 'business as usual' developments for NC. These narratives were checked for consistency (i.e. identifying and resolving instances in which assumptions within the same narrative contradicted each other) and then written-up as scenarios for NC in Scotland. Researchers also added climate projections to each scenario, based on The James Hutton Institute Climate Data Visualisation.

The three scenarios that were generated (Appendix 4) are called: *1) Continuing current trends; 2) Community values for resilience; 3) Exploitation and vulnerability.* They can be used as part of this toolset to stimulate discussion about potential changes and conditions that could affect NC in a specific landscape, under the different scenarios, as well as potential threats, uncertainties, opportunities, and responses. Participants may use maps of NC in a landscape, generated through the 'mapping values' step, as a starting point, and consider how the information recorded in the map might change under each scenario, for their landscape. Discussions around this may then help people respond to the Q method in a way that represents what they want to protect and promote, which in turn shows what they value.

To stimulate discussion around these scenarios, we suggest the following questions for consideration. Participants may be split into smaller groups to consider the three scenarios, separately, but it is important that they come back together to share what they discussed and learned:

1. Looking at the maps produced, how do you think the NC that you value in the landscape would change under each scenario?
2. Looking at the maps produced, how do you think the distribution of values you associate with NC in the landscape would change under each scenario?
3. In each scenario, what threats do you perceive to NC in the landscape?
4. In each scenario, what opportunities do you perceive for NC in the landscape?
5. How might we respond to the threats and opportunities identified in the scenarios?

What output does it generate?

Discussions in relation to the scenarios may be recorded by taking notes or audio recordings that can later be transcribed. Notes and transcripts may then be analysed to identify themes in relation to potential future conditions that could affect NC in a particular landscape. They can also be used to help identify the kinds of NC, and the relationships with nature, that people value and wish to protect and preserve. These findings may then be used alongside the results of the Mapping Values and Q method exercises, both to understand how people value NC in a landscape, and to help inform planning and decision-making for its management and use. An example of conversation with implications for land use changes is proposed at Step 3.

What resources are necessary?

Developing scenarios from scratch can be very time-consuming and skilled facilitation is required for conducting exercises in a robust way (Oteros-Rozas et al., 2015; Thomson et al., 2020). We therefore recommend using the scenarios we have developed for the national level in Scotland and using them as contexts in which to consider how NC in a specific landscape would be affected. Using the scenarios for discussion may be achieved relatively simply, by asking participants to read through the three scenarios and using the suggested discussion questions as points of discussion. However, as with all group discussions, PSP requires skilled facilitation to ensure a balanced, fair and relevant conversation between different participants, and to maximise the potential benefits of this method (Poskitt et al., 2021).

Step 3- Mapping values

Goal

This approach captures the spatial information related to the ecosystem services of habitats through public participation GIS (PPGIS) and discuss likely changes under the scenarios developed in the Step 2.

What is it?

This is an approach that can be implemented using open-source GIS such as *ArcGIS Earth* for capturing and integrating spatial datasets in the study area to support audiences' discussion of NC values. It can be used for scientific research as well as engagement with the public on issues of landscape change. It allows people to be immersed in computer models to explore uses, benefits and features of landscapes.

How is it implemented?

The approach is implemented by asking stakeholders to select a certain number of points on a land cover, land use or satellite map, visualised through a GIS tool. Each point or "dot" represents a specific aspect that the research team wants to investigate (for instance the presence of scenic views, or areas that are suitable for forestry, or individual ES produced by a habitat). Collecting points on different values or benefits can be useful to discriminate stakeholders' preferences but also for producing information for planning future uses of land, possibly discussing changes in benefits and their localisation under different scenarios. Appendix 1 shows the list of values, expressed as ES, used in the implementation of this approach at Glensaugh farm (Scotland).

If dots are collected on a physical map, then these can be digitalised respecting the appropriate georeferencing system. Operating directly on a digital support is good practice for limiting the burden of converting the physical maps into a digital product and reducing the potential mistakes of digitalisation. The advantage of using ArcGIS Earth resides in its simplicity, and possibility to operate at nearly zero cost. It does not require a licence, and it is possible to select any area in the world and import personal maps.

The implementation of this approach can be done in small groups (we suggest a maximum of 5 people) giving sufficient time to each person to allocate dots on a map. While there is no need to be prescriptive around the exact number of dots that each participant may select, the goal is to suggest a ballpark number that incentivises stakeholders to be selective and prioritise a limited range of important values or benefits. Twenty to thirty dots per stakeholder are suggested as a rule of thumb, in order for the group to select a maximum of 100-150 key areas. Several group collections are necessary to select several hundred dots that can be graphically and statistically processed in a second step.

What output does it generate?

The GIS mapping approach generates a series of vectorial maps of preferred uses or values. These can be rasterised, and some calculations can be made to emphasise the area covered by the most prominent ecosystem services, the frequency of each benefit in different habitats or land uses, and the "heat" map showing where the highest values are located. A table summarising the above information can also be proposed.

In implementing this approach to our case study, the Glensaugh farm, we have selected benefits expressed as ecosystem services building from several ES classifications: the CICES (v.5.2) and the Nature Contribution to People proposed by IPBES (Moreira et al., 2024). While the list can be vast, we considered 14 ecosystem services, after an internal consultation within the research team (Appendix 1). Discussion within the research team and with stakeholders is important to make the correct selection of ES that represent a spectrum of contextual values for the area of interest.

An example of how ES can be individually selected is reported in Figure 3, where we considered the aerial map of the Glensaugh farm (within the red boundary) in which we have indicatively selected three areas using different geographical elements, a dot (point 1) a line (yellow segment) and a polygon (brown and red rectangles). The geo-localisation of all the dots selected at Glensaugh during a workshop, described in the section "*Testing the toolkit at Glensaugh farm*") with a descriptive classification of their value under different land uses is reported in the Box 1.

Figure 3: Example of how to make the selection of ecosystem services in the area of interest using polygon, punctual and linear elements in ArcGIS Earth.

What resources are necessary?

The collection of data can be organized through an in person or online workshop. We opted for an in-person workshop where a facilitator leads the conversation on the ES that the area of interest can generate and supports the localization of data on the maps according to the preferences elicited by the participants. The resources needed to complete this operation are the same requested to organise the focus group. In addition, it is necessary to have a desktop or laptop for any breakout group and an external monitor to better visualise where the preferred values will be localised. The time necessary to complete this operation depends on the size of the area and of the group. For small groups of 4 or 5 people allocating one hour can be sufficient.

The analysis is more time demanding than data collection and requires GIS skills. Possible elaborations refer to the aggregation of all the data by categories (for instance the ES groups of provisioning regulating and cultural services provided by CICES), the quantification of the size of the area where values (benefits) are mapped, and the investigation of the habitat features, typologies and size where benefits are distributed.

In case of lack of availability of GIS skills, the aggregation of data can be made using an old fashion approach based on very thin semi-transparent paper overlayed on to the habitats or land use map to individuate the areas where benefits are localised.

BOX 1: Example of GIS mapping approach at Glensaugh

The participants at the workshop were provided with a paper map of Glensaugh farm with an OS background map to help with navigation, while the Land Cover Map 2023 (10 metre raster pixels) was overlapped to the satellite images of the farm using ArcGIS Earth to allow participants to select points relating to ES types (provisioning, regulating and cultural) to different land uses.

Stakeholders selected more than 100 points focussing principally on provisioning services (see Annex 1) as shown in the Figure 4 and Table 2.

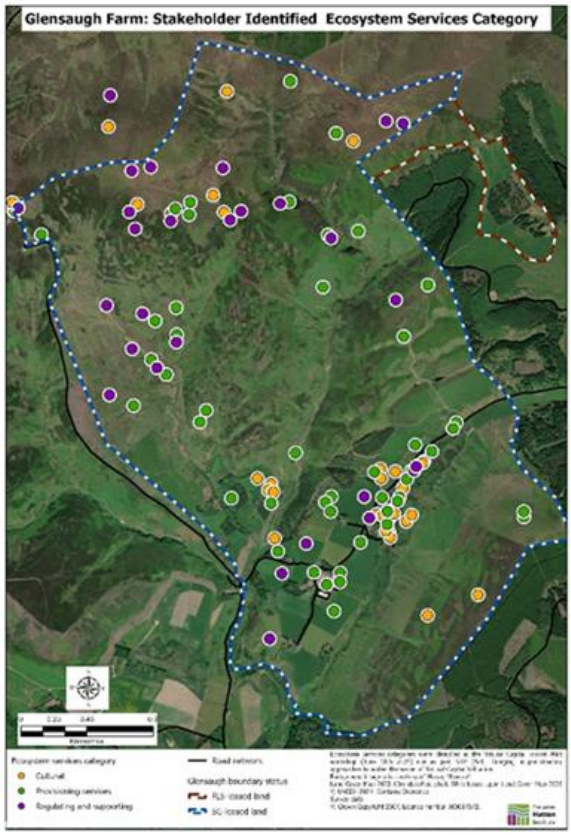

Figure 4: Data points collected at Glensaugh representing cultural (amber points), provisioning (green points) and regulating services (purple points).

Table 2: ES categories selected during the GIS participatory mapping approach

ES type	N. points	%
cultural	37	33.04
provisioning	47	41.96
regulating	28	25.00

The points were then exported from ArcGIS Earth to shapefiles and analysed in ArcGIS Pro to extract statistics around land cover in relation to the ES categories identified by the participants. Information was summarised in tables using Microsoft Excel. An example is provided at Figure 5 showing the expected cultural benefits by land use. Recreation is dominant especially in freshwater because of the presence of a loch supporting angling activities. The same land use seems to trigger wellbeing, while relational values such as sense of belonging and sense of place are stronger in the heather and grassland habitats.

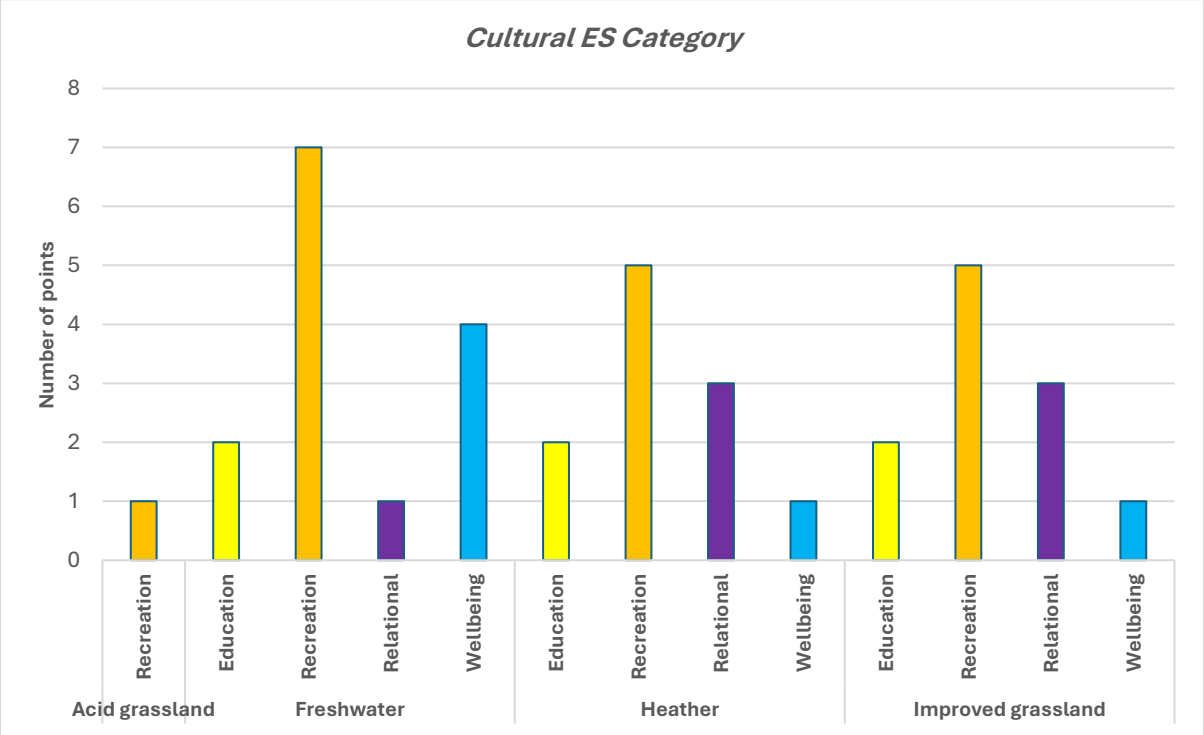

Figure 5: Statistics on the frequency of cultural benefits in different land uses

Step 4- Exploring and categorising stakeholders' perspectives by Q method

Goal

The Q-method enables researchers to discover similarities and differences across the attitudes and perceptions of individuals regarding NC and ES. By applying the Q-method we can identify the heterogeneity of attitudes, perceptions, values and can examine areas of consensus and disagreement among people, a form of knowledge that we argue is useful in specifying, selecting, and evaluating decision-making. This is an important target for policy analysis and evaluation.

What is it?

Q-method was developed in psychology (Stephenson, 1963). It is a participatory-based, systematic and rigorous scientific tool designed to reveal and examine subjective attitudes and perspectives; to provide insights into attitudinal diversity and human preferences; to identify criteria of the issue in question that are important to people; and to explain major factors influencing the heterogeneity of stakeholder beliefs (Watts and Stenner, 2012). This method combines qualitative and quantitative tools (Brown, 1999, van Exel and De Graaf, 2005) and incorporates elements of behavioural studies into action research (Nijnik et al., 2014, Miller et al., 2009). Comprehensive information about Q and its comparison with standard R analysis is available in Addams and Proops (2000), Brown (2004) and van Exel and De Graaf (2005) and others.

How is it implemented?

First statements are designed through a concourse analysis when knowledge is derived from interviews, written narratives or can be comprised of discourses and media (Davies et al., 2005; Brown, 2004). Commonly, statements emerge from communication with stakeholders. However, they can alternatively or in combination be derived from secondary sources (McKeown and Thomas, 2013, Stevenson, 2015). Next, respondents are asked to sort a set of statements representing positions on different sub-elements of the issue in question. These statements should, as closely as possible, represent the entire communication on the issue, i.e. the *concourse* (Stevenson, 2015). The sorting is usually done on a specified scale (usually using a normal distribution chart) and the result is what is called a Q-sort, i.e. the formal model of each respondent's attitudes. Then, each Q-sort is correlated with every other Q-sort, and their inter-correlation matrix is factor-analysed. This potentially enables the identification of attitudinal clusters (Brown, 1999); and, because these clusters are associated with respondents, the technique enables linking the identified clusters (typologies) of attitudes not only to subjective perceptions but also to the individual background characteristics of respondents. The resulting Q-sorts represent the attitudes people have, allowing researchers to suggest some underlying (societal) values that seem to be associated with certain discourses unveiled through the analysis (McKeown and Thomas, 2013). The final steps included interpretation of the social discourses unveiled through the quantitative analysis; contrasting the value outputs with the socio-economic background of respondents; and verifying and

communicating the results with/to respondents. The process from data collection through to results can be shown as follows:

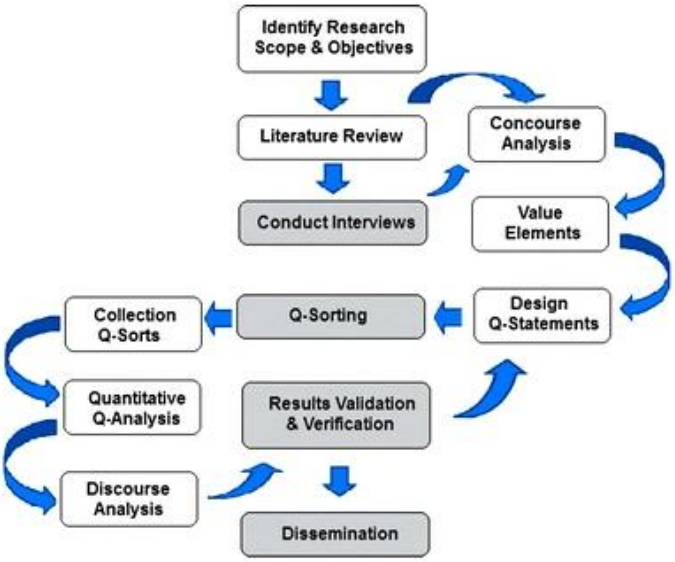

Figure 6: Steps necessary to implement the Q method (Nijnik et al., 2014).

The Q-method allows for a rather simple data set (Robbins, 2005). As many as 30 participants is usually enough because most of the data in this type of analysis derives from how much information is implicit in each participant's Q-sort (Barry and Proops, 1999).

What output does it generate?

The 'factors' (i.e. *attitudinal groups*) identify new uncorrelated choice variables that capture the common essence of the correlated individual Q-sorts (Nijnik et al., 2014), capturing the variety of individual attitudes, perceptions, values etc., and structuring them in such a way that different 'common discourses' emerge (Stevenson, 2015); thereby allowing a comparison of key differences and similarities between the identified '*factors*' and an explanation of why people may have their beliefs. For instance, in the implementation of the Q method at Glensaugh we used 30 statements describing a range of values and management strategies for forests, peatlands and agricultural assets. It was possible to clearly distinguish three groups, the first addressing stakeholders who value NC for a plural set of values with focus on relational and intrinsic values; the second considering the sustainable use of NC supporting ecological functions managed by local communities; and the third focussing on economic benefits that NC may generate. See details in Appendix 8 for a rapid view on how the Q statements are elaborated and a short narrative produced for each group.

What resources are necessary?

Key resources are participatory skills, knowledge of the Q method, computer literacy, access to open source software packages *qmethod* working under R to run factor analysis, knowledge of the concourse and discourse analysis and other qualitative as well as quantitative research methods applied in interdisciplinary social sciences. Half a year of full-time work by two researchers. What's good: it's relatively cost-efficient.

What are key limitations?

Respondents may find the completing of Q sort charts difficult and usually need supervision (otherwise largely educated individuals of a certain age can take part). Research results are case and context specific. We cannot argue that the method allows for extrapolation, and we can't transfer our observations elsewhere and generalize the results. Seen more in Nijnik et al (2018) and Nijnik et al (2016).

Step 5- Eliciting socio-cultural values

Goal

The goal of photo-elicitation, in this toolset, is to provide opportunities for participants, as individuals, to highlight social and emotional values that they hold for NC in the area in question. The use of photography, a method which encourages participants to feel and create rather than necessarily to intellectualise, may help them to access their tacit emotions, memories, somatically embodied experience and sensory experience. This encourages the drawing out of deeper, more personal values which may not come through as strongly in other methods used in the toolset. As such, this method aims to elicit an extra layer of information to enrich understanding of values held by local people for NC.

What is it?

In photo elicitation, participants produce narratives in photographic form and then talk about these images and what they 'mean', later, during interviews (Kong et al., 2015; Squire et al., 2014). Photo elicitation was developed as a method of investigating local environmental stressors. It has previously been used to explore community values and preferences around environmental change, and around policies and land management practices that impact upon local areas. In this sense it can provide opportunities for local people to participate in decision-making processes.

How is it implemented?

In photo elicitation, participants are asked to take photographs that represent their everyday experiences and are then interviewed qualitatively to reveal the meaning of this photographic narrative. Analysis of the photographs and the interviews are carried out by the researcher (Kong et al., 2015; Berbés-Blázquez, 2012).

Figure 7: A photograph of a Meadow Pipit Fledgeling taken by a participant as part of the photo elicitation exercise.

For example, in this case, participants were asked to take 6 photographs of the NC, or nature, that they value in the Glensaugh area (or, if they were not based at Glensaugh, in an area that held meaning for them). They were asked to do this while taking part in activities they would normally carry out there, such as walking, working, or passing by. Figures 7 and 8 show two of the photographs that participants emailed to the research team. Subsequently a semi-structured interview was held, where the researcher asked participants to first describe each photograph and reflect on it, to describe any memories or stories the photograph made them think of, to talk about how the photograph illustrated what they valued about NC in the area in question, to think about whether it illustrated any risk to NC, and finally, to describe how the photograph made them feel. Participants responses were then analysed qualitatively using thematic analysis.

Figure 8: A photograph of Loch Saugh taken by a participant as part of the photo elicitation exercise.

Lessons learnt from this process were that to engage participants it is best to carry out the exercise as part of a workshop rather than asking people to take photographs in their own time. We found that only two of our workshop attendees took part in the activity, despite there being enthusiasm for the method itself during the workshop. As such, rather than having people take photographs at a later date whilst carrying out their normal activities, it would be more effective to ask people to take part in a structured activity as part of other collective activities. The photographs themselves, however, should not be taken collectively – people should be asked to go out into the landscape and take photographs as individuals, and then to reconvene at a later time. Interviews can then be arranged individually after the workshop.

What output does it generate?

Photo-elicitation generates a set of photographic images and matching interview transcripts which, together, can be seen as narratives about deep personal values, meanings, feelings and perceptions in relation to specific landscapes and the NC found there. These might not otherwise be available to the researcher (Kong et al., 2015). The narratives which are generated may describe events that happen over time, identities, histories, emotions etc and are useful for finding out about things from grass roots perspectives. They sometimes reveal interesting counternarratives (Squire et al., 2014).

Narratives have 'particular social effects', can affect people's understandings and actions and can help us understand how meaning is constructed in relation to social, cultural and political contexts. Narrative telling can, in itself, be political, since it is capable of imagining alternative

futures / outcomes and so can create the possibility of change. It can reveal how stories can be silenced / contested or reveal hidden / unnoticed things (Squire et al., 2014).

Narrative research gives real people the opportunity to interpret, question or resist dominant narratives. It gives voice to personal experience and can motivate sociopolitical action (Squire at al., 2014). In this sense it can be very inclusive – however, its level of inclusivity depends on 'who' is asked to provide narratives and how accessible the means of gathering narratives is to them. Photo elicitation can be a way of exploring local stakeholder knowledge and perspectives, providing the opportunity for the documentation of participant 'observations' and allowing the framing of these observations to remain in the control of the participant (Kong et al., 2015).

The exercise carried out at Glensaugh with two participants clearly demonstrated the usefulness of photo-elicitation for obtaining deeper personal and social values. Participant responses to being asked to talk about their feelings varied, perhaps reflecting their levels of comfort at sharing emotional information. However, in practice, both revealed deeper feelings about the NC and shared memories that demonstrated the importance of the landscape and sometimes of the specific NC pictured. In particular, one participant expressed NC values in relation to historical and meaningful events in his life, while another linked their values to generational histories amongst the communities in the area.

Talking about the Loch through a personal lens and comparing experiences of different angling clubs enabled one participant to come up with an idea for creating a fishery in a nearby burn. He said 'I never thought of that before, until all of this, so, the toolkit kinda, kinda opened my eyes to that… I thought that was quite neat'. The participant also reflected that he had surprised himself, during the photo elicitation exercise, since most of the photographs he had taken were not of the Loch itself but of the surrounding area. He felt this revealed that there was more about the areas that he found 'really cool' than he had thought. Whilst the photo-elicitation exercise did draw out information on natural capital assets and ecosystem services, with strong representation for both 'biodiversity' and 'recreation'. The largest proportion of responses pertained to the more personal benefits participants felt they obtained from natural capital. In particular, these included mental health benefits, benefits from nature watching, sense of place, and feelings of belonging. Participants also discussed the social benefits they obtained from being at Glensaugh with others, and strong feelings of stewardship for the area. The exercise also brought up a variety of disbenefits or risks to the natural capital in the photographs, in relation to personal experiences of Glensaugh.

Comparing the types of values elicited here to the types of values elicited through the other methods of the toolset, it is clear that photo-elicitation is capable of generating information on a different, deeper set of personal, individual and social values that the other methods do not necessarily draw out. This makes photo-elicitation an excellent complement to the other methods in the toolset for understanding individual and community values related to NC.

What resources are necessary?

Skills in photography, and in facilitating workshops to teach photography, may be necessary if advanced equipment is used (equipment needed can include cameras / tripods and audio recorders for recording interviews / group discussions), however it is possible and perhaps preferable in this case to collect visual material from participants through photographs taken on their own mobile phones or using single-use cameras (Sherren et al., 2012). Photo editing software may be necessary, and venues for meeting participants / exhibiting outputs. If travel is

involved, financial resources may be needed for researcher accommodation / subsistence. Generating narratives using visual methods can be time consuming - if narratives are being collected in a group rather than individually, skills in facilitation are needed, and if interviews are being carried out, interview skills will be required. Skills and access to Nvivo may be required for thematic analysis. If the visual narratives will be presented at, for example, an exhibition, or online, event management skills / digital skills are needed.

Step 6- Quantifying ecological and economic value

Goal

This part of the toolkit describes how to collect and analyse quantitative data on a range of ES and the natural assets available in the area of investigation. The goal is to understand the ecological state under the current uses and possibly predict evolution under different scenarios. Monetary inference of the biophysical values can be made.

What is it?

This is an approach that requires a combination of information on the extent of natural resources (Barbier, 2019; Bateman and Mace, 2020) such as geology, soil, air, water, and living things (SFNC, 2016) for the area of investigation to be retrieved, through secondary data, and supplemented, if necessary, by primary information collected through questionnaire survey. In addition, it is worthwhile considering the flow of 'ecosystem services' such as energy, water, plant, and fibre growth, from which people derive benefits (Bateman and Mace, 2020).

How is it implemented?

Implementing an approach that describes physical and monetary benefits generated by NC is not straightforward. It should be operated according to guidelines describing how to create a physical and monetary flow and stock for environmental assets, such as timber, land, minerals, or water in connection to activities. Guidelines working for the construction of ecosystem accounts are provided by the UN system of environmental economic accounting- ecosystem assessment (SEEA-EA) (2021), but others are proposed such as the one focusing on the dependency and impact of businesses on NC (NC Protocol – Capital Coalitions, 2016). Following the UN SEEA-EA standard, three biophysical and two monetary accounts are suggested: (i) ecosystem extent (size) accounts; (ii) ecosystem condition (quality) accounts; (iii) ecosystem services flow accounts in physical terms; (iv) ecosystem services flow accounts in monetary terms; and (v) monetary ecosystem asset accounts. While it is difficult to go deeply onto these 5 accounts, the suggestion is to focus on accounts (i), (ii) and (iii).

First account: Information for measuring the extent of habitats can be retrieved by land use maps, available at different scale such as the Corine land Cover, or for the UK by the UK CEH Landcover map. The analysis of the maps requires at least some skills in the use of GIS in order to extract information on the habitats and classes of use for the area of interest.

Second account: this refers to the quality of habitats, resources and ecosystems. Quality may refer to a range of physical characteristics and regulating ecosystem services. For instance, a broad range of chemical and physical properties of soil may say a lot about the health of soil, highlighting information around structure, density, presence of certain elements, etc. Several indicators referring to the condition of a range of ecosystems are proposed by the UN SEEA-EA

(UN, 2021). This information cannot be easily obtained on the ground if not at a high cost. It requires time, money and competencies in carrying out analysis and interpretation of data. Similar consideration can be made for other resources such as the quality of water, or the quality of a forest that may be impacted by pests, diseases, and reduced primary productivity. For the purposes of the NC assessment suggested in this report, it is better to consider what resources make part of the area of interest and then look for information in the literature. Examples of indicators that measure the condition of habitats and ecosystem are provided by several guidelines including the UN SEEA (2021).

To make an example, The James Hutton Institute has operated in this area since the beginning of 2020 describing the implementation of the NC approach at the farming scale. A report on biophysical and monetary indicators and economic analysis with implementation at the Glensaugh farm was proposed by Ovando (2020). Further guidelines on how to implement the NC approach in the farming context at landscape scale have been proposed under the H2020 FRAMEwork project (Martino et al., 2023; Martino et al., 2025).

Third account: this account refers to the flow of ecosystem services. The flow of ecosystem services can be also seen as an indicator of quality and considered as part of the second category of account. For instance, emissions of soil carbon are an important indicator that indirectly describes the quality of soil, and more in detail the soil management strategy adopted to conserve soil properties, such as regenerative farming management practices for the protection of agriculture, peatlands and forest soil. The quantification of provisioning services (mainly marketed good such as crops, timber, livestock, fish, etc.) can be retrieved by data stored in databases, summarised in reports or by primary investigation through a questionnaire survey (an example is available in Martino et al., 2025). Regulating services are more difficult to measure. The report produced on the formulation of the NC asset profiling at the Cranborne Chase farmer cluster (England) (Martino et al., 2025) explains how to combine primary data with secondary information and adopts simple mathematical models to measure biophysical and monetary aspects of ecosystem services generated within the farming system. It shows how to produce statistics within each farm and the farmer cluster for crop and livestock production, carbon emissions, carbon sequestration, soil erosion, avoided oil erosion under regenerative farming practices, biodiversity of birds and pollinators, and how to assess intermediate benefits (in biophysical and monetary terms) of soil fertility and crop pollination.

The use of a software can be important to generate quantitative data and geo-localise values minimising effort and reducing time of operation. Over the last 20 years several tools have been produced. Some of them run on GIS platforms with different degrees of complexities. One example is represented by InVest, a suite of free, open-source software models used to map and value the goods and services from nature. A recent GIS software, the Natural Capital Tool (NCT), modelling ecosystem services in the Scottish landscape has been produced by NatureScot (in beta version at the time this document is delivered-December 2025). This is a free spatial tool to assess the biophysical and monetary values of ecosystem services in Scotland under the current land uses and alternative scenarios (both changes in land use and different land management, for instance by introducing regenerative soil management practices). The tool can be used to map habitat connectivity and landscape opportunity. Alternatively, it is possible to use data available on land use such as livestock, forest, and agriculture production, to characterise change in NC under the current use and likely alternative scenarios (see Box 2).

What output does it generate?

The information collected through secondary and primary sources can be used to generate a series of tables and graphs, including bar plot, pies chart, and radar plot. For instance, Figure 8 refers to the classification of a series of indicators that measure crop production and ecosystem services at the Cranborne Chase (England), under the project H2020 FRAMEwork, classified according to the intensity use of nitrogen. Because different indicators are characterised by different units of measure, to make a comparative analysis they were standardised (with mean zero and standard deviation one). From Figure 9 it is evident how fewer intensive systems (blue and green lines) can supply higher environmental benefits, while the arable farming system (red line) using 300 kg per hectare of nitrogen, is more productive, demands higher services such as crop pollination but is not able to generate high levels of biodiversity and regulating ecosystem services.

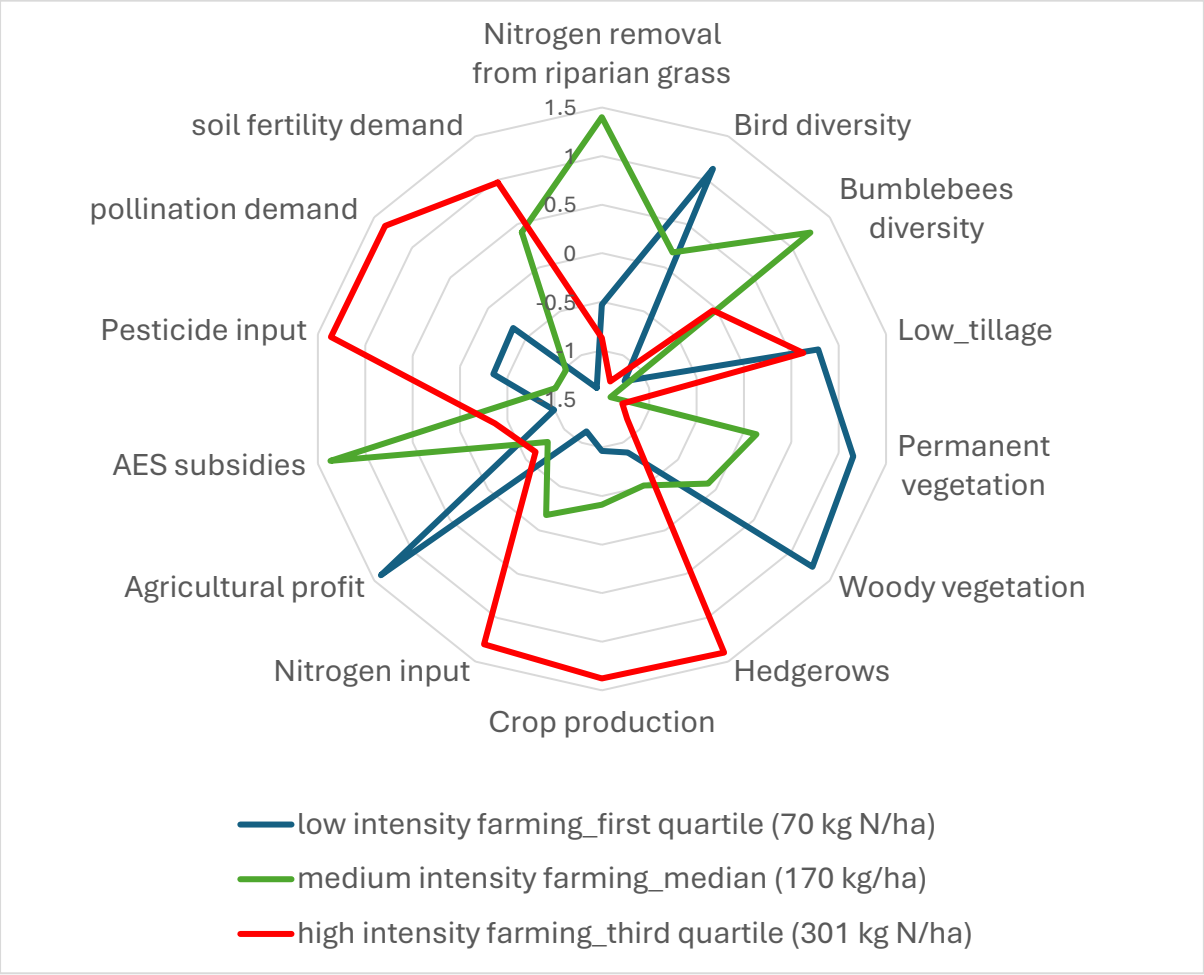

Figure 9: Example of environmental information from different indictors of natural capital explaining the farm system using a radar plot (Martino et al., 2025). The classification between farms is based according to the intensity use of nitrogen.

What resources are necessary?

The implementation of the NC approach using a range of accounts can be demanding and time consuming. It can be also very technical and requires a combination of roles in the team dealing with geographical, environmental and economic data. We recommend dedicating at least two people of the team to the analysis of NC. Several months up to one year can be necessary to

retrieve, collect, homogenise, and integrate the current gaps by primary observation and formulate (if necessary) the analysis and visualisation for each of the indicators describing extent and condition of NC.

Box 2: The implications of land use changes under scenarios at Glensaugh farm for achieving net zero

We used available secondary data on land use and agricultural management at Glensaugh, and information on carbon sequestrations of different ecosystem and emissions caused by soil erosion in Scotland to model how the net changes in carbon emissions may change under different scenarios.

For the land use reported in the Table 1 of Appendix 7 (improved grasslands, heather, acidic grassland, and forestry and woodlands), we assessed carbon missions caused by soil erosion, carbon emissions of peatlands, and carbon emissions arising from the use of energy, fertilisers and originated by livestock. E also considered carbon sequestration of grassland and forests. A simple net carbon balance is shown in the Figure 10 where it emerges that Glensaugh is a net emitter of CO2 for 315 tCO2e per year (using 2018 livestock and farm management data). According to Figure 10, there is good capacity for the current land uses to sequester carbon although this is compensated by losses coming from peatlands and livestock. To achieve net zero, it is necessary to intervene in the future by restoring the peatlands under degradation, reducing livestock or managing differently its diet. Changes of carbon emissions are proposed under two different scenarios discussed with stakeholders. In none of them the farm becomes carbon neutral. Details are provided in the Appendix 7 that also shows for some indicators dependency of the farm on NC.

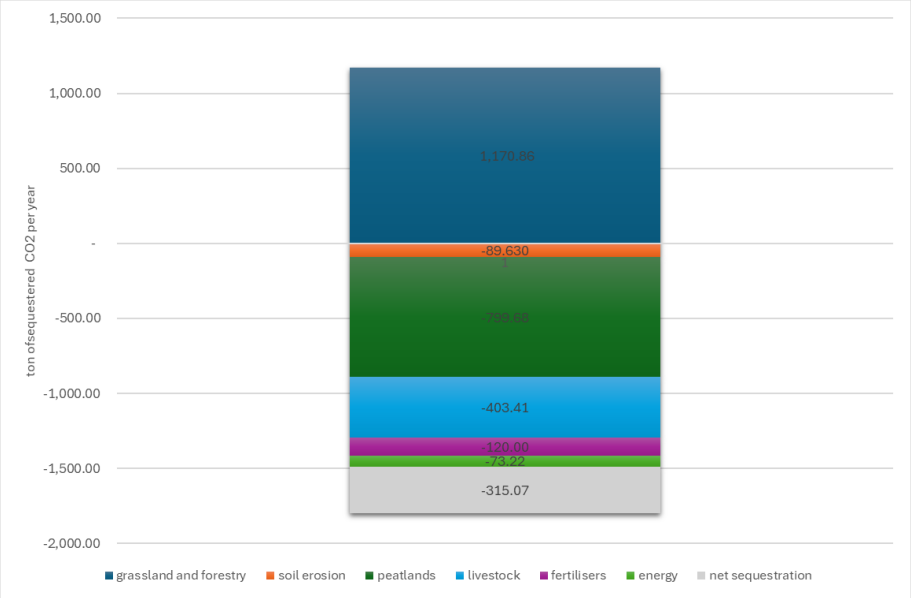

Figure 101112: 1314Emissions and sequestration of different land uses and farm management aspects at Glensaugh

Step 7- Planning decision by deliberation of the total social value

This step is not yet applied in the project D5-1, and we cannot provide any example or feedback. We briefly describe the main peculiarities that characterise its implementation.

Goal

The goal of this step is to reconcile the information acquired in the previous activities by discussing one or more solutions that can accommodate the interests of a range of stakeholders to minimise conflicts.

What is it?

This is a discussion with the stakeholders that contributed to the implementation of some (or all) of the previous steps. Deliberation is at the core of the approach to reconcile the information coming from the implementation of methods and tools proposed in the previous steps.

How is it implemented?

This step can be implemented by summarising the results arising from the economic and socio-cultural values previously described under the current context (status quo) and variations proposed under the scenario narrative. Because of their different nature, these indicators cannot be aggregated. A possibility is to plot these indicators using a common scale, for instance by transforming them to a standard range, often 0 to 1, or by normalising them to have a mean of 0 and a standard deviation of 1. Qualitative information summarising (contrasting) opinions of different stakeholders can be also proposed to enrich the discussion.

What output does it generate?

The normalised values coming from different set of variables can be presented using a spider web or radar plot. An example was proposed in the Figure 8. The proposal of indicators summarising the condition of NC under scenarios (see Appendix 7) can stimulate debate on conflicting values, represented by the articulation of the socio-cultural aspects, ecological dimensions and monetary aspects associated with NC. This analysis demands further development of agreed principles which may in turn require deliberative approaches to help decision-makers choose among alternative options (Pascual et al., 2023). In addition to the graphs, it is possible to use digital maps. The possibility of reconstructing the landscape using 2D or 3D models according to the information acquired during the scenario planning exercise can be used to present stakeholders the new aesthetics of the landscape and facilitate the discussion (Box 3).

What resources are necessary?

Resources necessary for this step are similar to those already described for the implementation of the GIS participatory mapping, and for the organisation of a focus group. It is necessary to have a desktop or laptop and an external monitor to better visualise graphs, tables and maps summarising the condition of the NC under different scenarios and eventually the new simulated landscape (using 2D or 3D virtual reality). In case of absence of digital facilities during the deliberative session, it is possible to show information on printed graphs and maps. Time necessary to complete this operation is around 2 to 3 hours. According to the number of stakeholders it is possible to opt for a plenary discussion or for breaking the participants into

small groups. An online event can be also a valuable solution to reduce time and cost of travelling.

Box 3: Example of a virtual landscape and its use in decision making

A 3D model was created to allow people to explore future landscapes. Figure 11 shows a local stewardship scenario produced from one of the workshop sessions in Aberdeenshire using the virtual reality environment with audiences local to the case study area. This highlights the recognition of risks to the existing community (e.g. flooding), mitigation measures, increased provision of local energy and amenities, and a desire to protect local resources (e.g. water quality and woodlands).

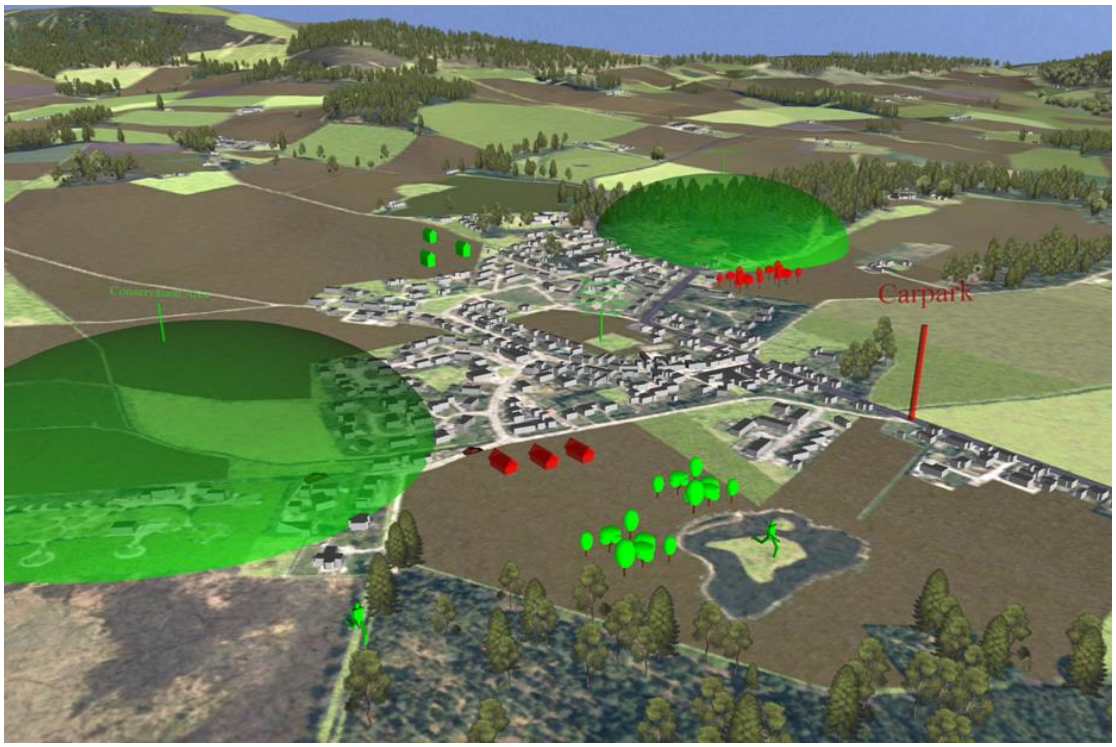

Figure 11: Overview of land use and landscape features developed from an audience local to the case study area

Testing the toolkit at Glensaugh farm

We tested some of the methods proposed in the previous sections at the Glensaugh climate positive farm, owned by the James Hutton Institute, on 10th June 2025. We invited national and local stakeholders focussing on farmers, anglers, foresters, and recreationists that showed interest in eliciting values emerging from the farm and understanding how these values may be protected. The organisations participating to this workshop are listed in the following Table 3.

Table 3: List of stakeholders participating to the workshop

Stakeholder	Number
The James Hutton Institute	3
Forestry and Land Scotland	2
NatureScot	2
Brechin Angling Club	2
Scottish Gov	2
Scottish Woodlands	2

The workshop was introduced by a brief explanation of the aim of the project D5-1. This was followed by an outline of the workshop activities and an introduction on habitats, past and current management of the farms and the main natural habitats (peatlands, woodlands and grasslands). After the initial presentations, the stakeholders were divided across three tables to discuss benefits and values at Glensaugh using these three methods:

1) GIS participatory approach;
2) Scenario elicitation;
3) Q method.

To carry out these three methods we provided some instructions. We decided to provide a list of ecosystem services (Appendix 1) for the GIS participatory approach to choose from and allocate them to a satellite map of the farm (additional maps of land cover and use were provided - see Appendices 2 and 3). Each participant could select up to 20 data points to allocate to specific areas of the farm and indicate the presence of provisioning, regulating and cultural ecosystem services. In the second approach, the scenario elicitation, we divided the stakeholders into three groups to which we gave each a scenario narrative (Appendix 4) describing the change at national scale in the economy, society and policy expected to occur by 2045. We asked the groups to contextualise the three narratives to the farm and envision any changes and impacts on the protection of NC and supply of ecosystem services. The three narratives summarise contexts that represent 1) the business-as-usual scenario, 2) a change in which community get more resilient; 3) an exploitative approach that reduces the resilience of nature. The last exercise consisted of a ranking exercise of 30 statements using a 9-point Likert scale (Appendix 5). The allocation of the answers was not free but forced by a triangular distribution. Stakeholders were forced to make trade-offs between statements, choosing 12 to which they could attribute a positive score (+1 to +4), 12 to which they should attribute a negative score (-4 to -1), and six to which they must attribute a neutral score (0- neither agreement nor disagreement).

We provide below some immediate ideas emerging from the implementation of these approaches and suggestions on how to overcome some difficulties. The general considerations emerging from piloting the NC valuation toolset at Glensaugh are aligned with the idea that

success can be achieved only if the stakeholders have a good knowledge of and interest in the area where the tools are applied. Pinpointing an exact location that generates specific value is an easy exercise only for those who have in-depth knowledge of the area. In our test, only a fraction of the stakeholders had a deep knowledge of the farm and were confident in carrying out the mapping exercise. Others could guess the benefits provided by certain habitats only because of knowledge and experience matured in other geographical contexts.

Splitting stakeholders between three groups with the presence of at least one member of the Glensaugh farm in each group was of help for the rest of the team when navigating the GIS mapping exercise. While we originally thought that restricting the mapping exercise to a limited number of key ecosystem services could facilitate their allocation on the map, it was suggested by our stakeholders to keep the list open. We decided to accommodate this, giving them the opportunity to include other ecosystem services not considered in our initial list. Overall, it was considered that an approach based on digitising the ecosystem services without following a structured method (such as a pre-selected list of ecosystem services) could be a better option. However, this approach requires reclassification, during the analysis, of all the data points acquired using a standardised classification of ecosystem services.

The discussion on the expected changes in the provision of ecosystem services under different scenarios was smooth only for two scenarios. The stakeholders of the table discussing change in NC under the business as usual and scenario and intensification and exploitation of economic activities were able to envisage a drastic change in the ecosystem services produced with increase in provisioning services and a drop in regulating services. Conversely, it was considered difficult for the remaining groups to link the wider contextual scenario with the specific values emerging at Glensaugh Farm, particularly when presented with ideas related to political and social changes. We considered that better facilitation assisted by the use of prompts to improve reflections can be proposed as well as a shorter narrative or a synthesis in bullet points of the three scenarios, alongside a few examples of how technological, political and social settings could contribute to explain changes in specific and geographically located values. Contextualising the narrative to the area of interest by providing some initial examples can help facilitate the discussion. An example of how land use at Glensaugh is expected to change under the scenario narratives is proposed in the Appendix 8.

The last activity based on the Q sort was not considered critical. This shows that the stakeholders had a clear view of values and management strategies for NC. However, two things can be better done to facilitate the delivery of this exercise: 1) explaining how data can be treated and what output can be generated, and 2) expanding the categories for the post Q survey to capture many more social-demographic aspects that can be related to the Q choices.

Separately from the activities carried out during the workshops, two stakeholders decided to participate to an additional activity consisting in the photo-elicitation approach. They collected pictures of the Glensaugh area and discussed their importance emphasising a sense of belonging, identity and other relational values in a follow up interview as described in the Step 5.

Considerations emerging from the feedback provided by the stakeholders participating to the Glensaugh workshop

We provide some considerations formulated by the stakeholders in a post workshop questionnaire survey (Appendix 6) on how to make a good use of the toolkit.

Stakeholders considered the toolkit a positive instrument to elicit NC values and inform decision making. However, it was suggested to work with a more balanced share of private and public actors and make it clear since the beginning how they can work together to generate a good output.

The toolkit was considered relevant for both land managers and researchers. Each single element of the toolkit was considered useful to explore different aspects of the value of NC. Scenario planning and Q methods were considered relevant to get a range of perspectives and facilitate categorisation of opinions, while the mapping exercise and photo elicitation can be used to geo-contextualise values and uses, propose changes under different policy or management scenarios and more importantly consider cultural and relational values that are commonly ignored under mainstream economics approaches.

As a third positive element the toolkit was considered a good approach for supporting councils, towns, or neighbourhoods planning. Its generic structure allows uses in any circumstances where there are several stakeholders involved in different types of projects and can be used for supporting continuous improvements if repeated at regular intervals (e.g., for the update of plans).

Conversely, the possibility of replicating the use of the toolkit at vaster scale requires careful planning. It was suggested that the tool can be mainly used for focussed aspects rather than providing broad views. Therefore, its best use should be for local implementations. It was suggested that the mapping tool could be labour-intensive at a bigger scale, therefore guidance on how to scale up the tool and use it in an efficient way would be helpful.

The local scale was considered a more suitable destination for the toolkit, but uses at broader scale cannot be ruled out.

Final considerations to make a good use of the toolkit

Using the full set of tools is not necessary although it can be advantageous to have a comprehensive view of the values at stake and how these can inform decision making. Each tool is associated to a specific step of the co-creation valuation process, and none is redundant. The full implementation of the tool allows the elicitation of the broadest range of relational intrinsic and utilitarian values that can be used when planning new projects and setting new programmes by obtaining insights from single stakeholders and communities. However, some partial knowledge may be available, and some steps can be skipped or re-arranged to suit more specific needs. This also depends on human and financial resources and the possibility of accessing specific data. We have chosen to work with free tools (e.g., ArcGIS Earth and test the Beta version of the Natural Capital Tool proposed by NatureScot) because they are characterised by intuitive features supplemented by clear guidelines. A certain familiarisation with these tools is needed before using them, while their use can be limited to the simple and basic functions illustrated in this report. For instance, the selection of data points to geo-localise ecosystem services can be simply carried out in ArcGIS Earth using the *drawing tool* to select points, lines or areas. We have suggested the selection of data points to which it is possible to associate a colour and a label. Then they can be extracted for further analysis by interpolating them with land uses by employing specific functions available in GIS software. Alternatively, in a more qualitative way, it is possible to visually depict where certain values emerge, avoiding a more detailed statistical analysis. The second tool, the NC Tool proposed by NatureScot, can be a good solution to extract, from the area of interest, biophysical and monetary information on a range of ecosystem services and to simulate planned scenarios to observe changes in these values. This is a simple and rapid way to implement the NC approach that alternatively would require more manual calculations. A possibility to implement in a more formal way the NC approach in agricultural farming systems is proposed by Ovando (2020), who showed a detailed implementation at Glensaugh farm, and by Martino et al. (2025) who has implemented it at the Cranborne Chase (England) farmer cluster.

In case it is necessary to cut out steps in the valuation process, it is possible to use secondary data for the area of interest on the main values at stake instead of investigating them through a discursive approach. Instead, we recommend using the scenario planning technique to derive a narrative that can be used to discuss which of the values localised by GIS mapping are expected to change. As a starting point, it is possible to use the narrative generated in this project (see Appendix 4) for any discussion of NC change happening in Scotland.

If financial and human resources are not sparse, a deeper understanding of more than human values and relational aspects with nature can be deeply investigated by eliciting them through a range of selected pictures taken by the interviewees. It is also important that resources are dedicated to the last step to discuss the broad range of values and deliberate on any trade-offs to reduce conflicts and eventually find win-win solutions.

Implementing the Q method in this framework can be considered a complement of (or in certain cases a substitute for) the scenario planning to understand and categorize individual perspectives and opinions on a specific topic, revealing both shared viewpoints and areas of disagreement. We recognise that this approach may be time-consuming and complex, requiring specific and professional skills for the implementation of the several steps that characterise it.

Nonetheless, its use may be valuable for understanding diverse perspectives on a topic, especially when those perspectives might be subtle or hidden, identifying and analysing shared viewpoints while also appreciating individual differences. This is particularly useful for exploring complex issues where understanding the range of opinions is crucial for effective decision-making. NC partnerships may use it for producing new land use policies that benefit from the ex-ante evaluation of the impacts on NC that different scenarios are expected to generate. The valuation framework can be also used to assess the achievement of policy targets in terms of their economic, social, and environmental impacts by introducing and monitoring indicators towards agreed objectives.

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Contact

Simone Martino: simone.martino@hutton.ac.uk

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Appendices

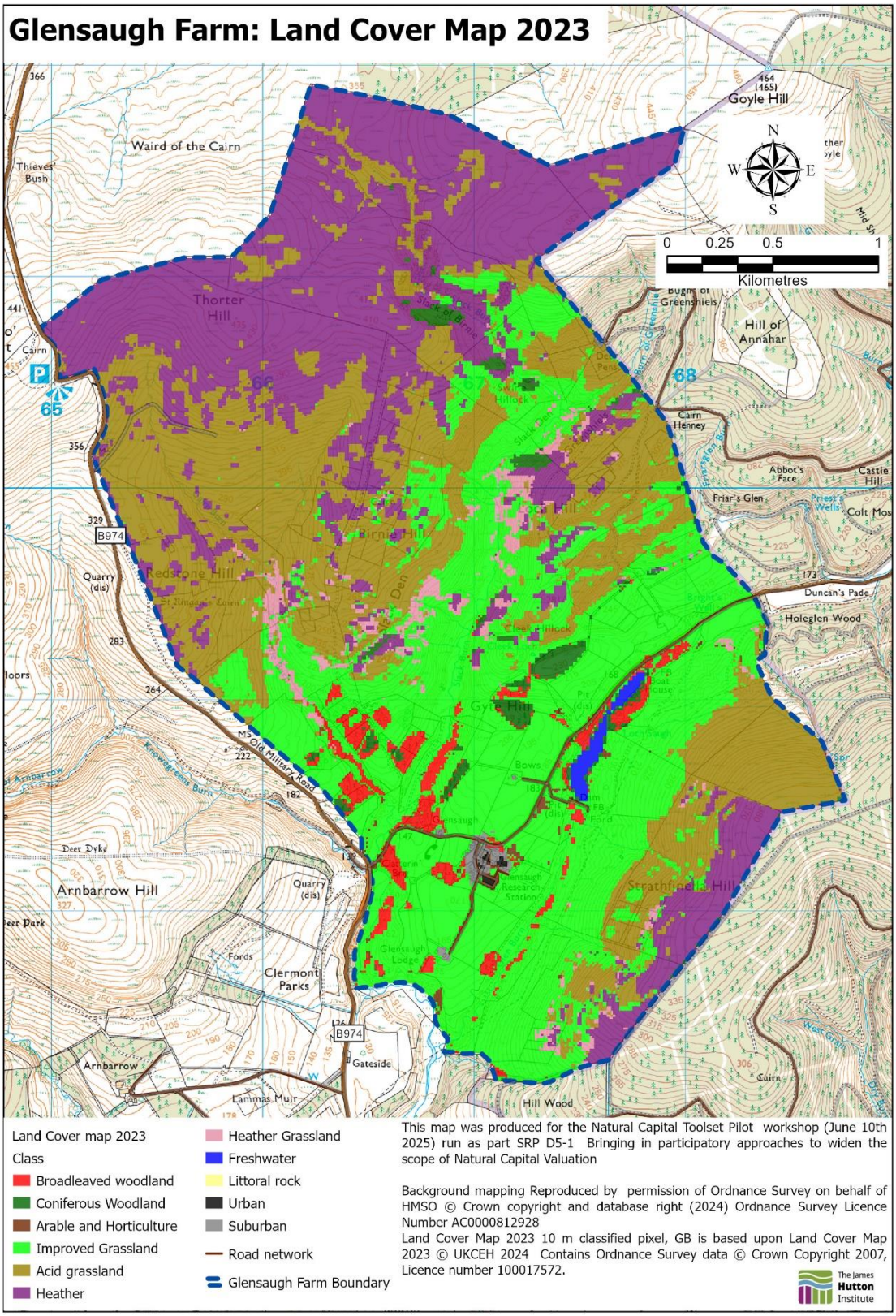
Appendix 1- Initial list of ecosystem services suggested

The following list of benefits is obtained selecting some categories of ecosystem services relevant for Glensaugh. These are selected from CICES (v.5.1) and the Nature Contribution to People proposed by IBPES, as reported by Moreira et al. (2024). Around 20 ES were originally selected, and then reduced to **14** considering those listed by Nature Scot and after judgement within the research team.

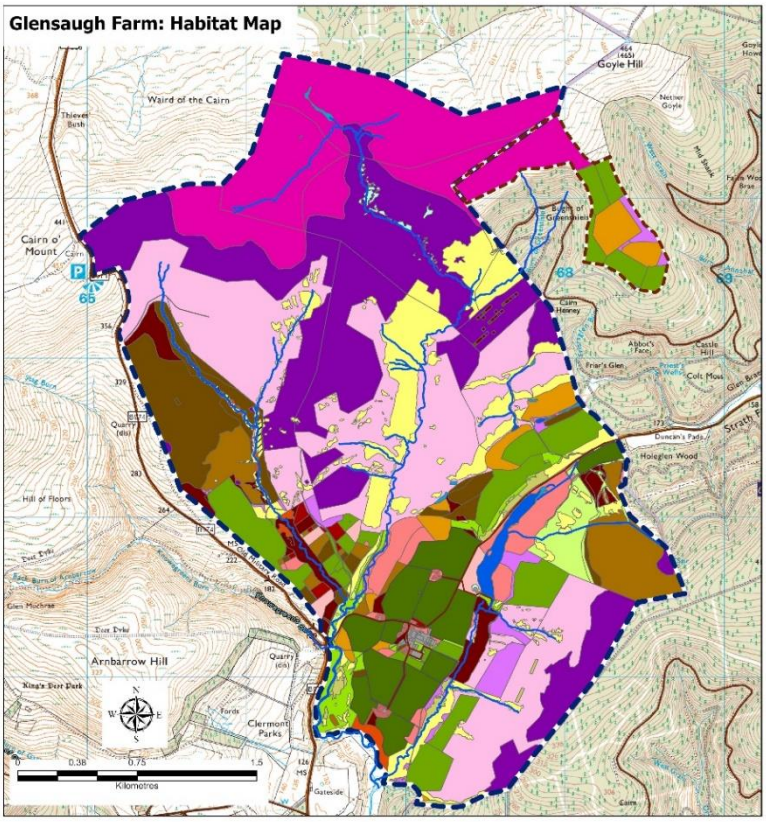
To each ES is associated a colour provided by Arc GIS Earth. The first 12 ES are associated with palette colour proposed by Arc GIS Earth. The last two ES (education and research and stewardship) were associated with two additional colours.

1) **Provisioning services:**
    a. Crop production
    b. Livestock production
    c. Timber production
    d. Renewable energy production
2) **Regulating and supporting services:**
    a. Soil conservation (control of erosion)
    b. Carbon sequestration
    c. Flood regulation
    d. Pollination
    e. Pest regulation
3) **Cultural services:**
    a. Recreational experience
    b. People's relationships with nature (place)
    c. Physical, mental health and wellbeing
    d. Education/research
    e. Stewardship

Appendix 2- Land cover map 2023



Appendix 3- Habitat map 2024



Legend

Habitat
- Active Bracken Control
- Bracken
- Garden
- Heath
- Heath / Upland grassland mosaic
- Improved Grassland
- Infrastructure
- Mixed Conifers
- Mixed Woodland
- Native Broadleaves
- Native Broadleaves & Conifers
- Native Broadleaves & Conifers (pockets with bracken/heath/upland grassland inbetween)
- Native Broadleaves (pockets with bracken/heath/upland grassland inbetween)
- Native Conifer
- Non-native Broadleaves
- Non-native Conifer
- Peatland
- Ponds and Lochs
- Rivers and Streams
- Rock and Scree
- Rush Pasture
- Scrub
- Semi-improved Grassland
- Unimproved Grassland
- Upland Grassland
- Wetlands
- Wood Pasture

Linear Habitats
- Rivers and Streams

Glensaugh boundary status
- Forestry and Land Scotland-leased land
- Scottish Government-leased land
- Road network

The Glensaugh Habitat Map was produced by The James Hutton Institute from documents and plans relating to the site. For more information please contact Scot Ramsay (Scot.Ramsay@hutton.ac.uk)

This map was produced for the Natural Capital Toolset Pilot workshop (June 10th 2025) run as part SRP D5-1 Bringing in participatory approaches to widen the scope of Natural Capital Valuation

The James Hutton Institute

Appendix 4- Narrative scenarios

Scenario 1 – Continuing current trends

In this scenario, technology is supporting the continuation of hybrid working, which enables more people to live and work in rural areas. This reduces transport emissions from commuters, and for some, living and working in a rural community encourages stronger connections with local nature, because they are constantly encountering the local landscape, and are therefore more strongly rooted in it. Additionally, growing numbers of people have multiple jobs and roles, which supports a more pluralistic rural economy, as well as support for local products and services.

However, on balance, local business continues to decline in rural areas, and there remains limited capacity for 'green' jobs. This still results in net outward migration of people from rural communities, especially young people. The aging population means funding for rural communities is diverted into healthcare to support the aging population, whilst for some people working from home means working longer hours, which results in them becoming more isolated, and in fact losing connection with their local area. This results in a loss of skills and knowledge for managing natural capital, as well as reduced demand, locally, for the services it provides.

Rural communities have limited power to enact change and preserve biodiversity. High-income second homeowners therefore wield significant power over how natural capital is managed. Tourism continues to be exploitative, providing only seasonal employment for rural populations, and causing degradation of natural capital. Peat restoration is occurring but continues to be slow. Large swathes of land continue to be managed for high-impact and unsustainable land uses, such as hunting, for the wealthy, whilst rewilding has yet to be properly defined and understood. Housing, businesses and infrastructure are often developed unsensitively, for example on floodplains, or without due consideration for local communities and their connections to the landscape.

Climate change issues are receiving greater attention, leading to increased action locally and nationally, whilst COP enables global collaborative action. Action against climate change is being taken, but progress is slow. Meeting Net Zero targets is a struggle and faces many challenges. Lobbying by proponents of extractive and high-emissions industries remains strong, and hybrid working generates greater usage of cloud servers, which results in higher emissions from supercomputers. Although nature finance is exploring the potential for blended finance and new markets, as well as developing codes and standards of good practice, it remains predominantly unregulated and voluntary, focusing primarily on uncertain and unstable carbon markets.

A hotter and drier climate places growing stress on natural capital, exacerbated by more frequent and intense climatic extremes. Trends of habitat destruction and biological change continue, while pests and pandemics proliferate. These changes require rapid learning about the ecological impacts of climate change, which helps improve management of them, to some extent. However, data about natural capital condition remains poor-quality, has limited national-level coverage and is not universally accessible. This makes accurately understanding and measuring the impacts of these changes a challenge.

Scenario 2 – Community values for resilience.

Under this scenario, rural populations are resilient and empowered through strong local governance, local democracy and local participation. Scottish Government policies promote local procurement, which helps to support circular local economies. Natural capital is commonly owned by local communities, or by partnerships of communities and other landowners. This ensures that benefits derived from natural capital are used for the benefit of local wealth and wellbeing.

The post-COVID-19 trend of hybrid working continues, encouraging increased immigration to rural communities, which promotes innovation and economic activity. This is measured against a high proportion of older people in rural communities, who ensure that wisdom, collaboration and shared skills are valued. In turn, this ensures the housing, services and infrastructure needed for growing rural populations are developed sensitively and in harmony with local landscapes.

Taken together, these drivers enable rural communities to have a stronger influence on the management of natural capital. The rootedness of rural communities in the landscape, and their nuanced understanding of it, contributes to positive management that is based on care, rather than extraction. Land is managed for multiple uses, including polycultural and regenerative agriculture, as well as well-managed conservation and rewilding. This strengthens the capacity for natural capital to provide 'regulating' services (e.g. water quality, carbon sequestration, controlling flows of water, soil nutrition). Community-led tourism also fosters a greater awareness of the natural capital that underpins and is affected by tourism, as well as a sensitivity to the diverse types of values associated with the landscape. This leads to greater demand among tourists to experience a varied and biodiverse landscape, and a less-exploitative model of tourism.

Increased efforts to combat climate change help attract more investment in private and integrated carbon markets. Nature finance develops rapidly via investment from multiple sources, including private finance and new income streams. This means more money is available for natural capital management, and there is increased spreading of costs through value for money and increased public-private finance. This growth in investment increases the economic value of natural capital. However, the strength of local governance and community ownership ensures that private investment in natural capital is conducted in a responsible manner. This includes recognition of a responsibility to preserve a holistic range of values, encourages transition to more sustainable business models, and works for the benefit of local communities.

Meanwhile, technological developments, including the role of cheap and accessible artificial intelligence, lead to improvements in the accuracy of biodiversity data. This enables better monitoring of the condition of natural capital assets, as well as the risks posed to them. There is better understanding of the impacts of climate change, as well as of changes to the biological balance, and how resilience may be achieved. These improvements in knowledge result in more informed resource-planning and decision-making, encouraging a joined-up and holistic approach to meeting 'Net Zero' targets. This strengthens synergies across policies and sectors, and fosters longer-term political decision-making. This more-informed decision-making also ensures that targets and incentives are tailored to be appropriate for specific contexts, which improves land management and enables targets (including carbon sequestration) to be met.

A warmer climate, with more variable rainfall, prevails, but the above socio-economic trends mean the health of social-ecological systems, and thus their resilience to extreme weather events is improved. This sets a positive trajectory for meeting future targets, and there is optimism that many of the effects of climate change, whilst felt starkly, can be managed and mitigated.

Scenario 3 – Exploitation and vulnerability

In this scenario, an intensive and extractive, capitalist economic model prevails. This emphasises intensive farming, monocultures, exploitative tourism, and extensive land use for energy production. Policies aimed at empowering local communities fail completely, and the power of large, corporate actors, such as supermarkets, is consolidated and strengthened. Economic benefits from the exploitation of natural capital therefore move outside rural communities to external actors. Unregulated nature finance creates unequal distribution of benefits. Targets are not made for the public good, and the possibility for investing in natural capital acts as a disincentive for companies to reduce emissions and change to more sustainable business models. Additionally, double accounting means the benefits of investment in natural capital are often not realised.

Meanwhile, a continued shift towards home and hybrid working creates increasing demand for housing in rural areas, but this is met without sufficient consideration for sustainability, service provision, or cultural sensitivities for local communities. Wealthy homeowners drive-up house prices, displacing local people from rural communities. This results in a loss of local resilience, through degradation of cultural and community values associated with place and community cohesion, as well as causing pollution and degradation of the natural environment, including increased risk of wildfires.

A warmer climate with increasingly variable rainfall and climatic extremes, combined with a degraded natural environment are compounded by slow and unambitious actions towards meeting Net Zero. Targets continue to focus on carbon, at the expense of biodiversity, and are increasingly ignored, or dropped entirely. Protectionist and politically isolationist policies, in relation to climate change, prevail. This means that actions to mitigate and manage the impacts of climate change on natural capital are failing, and its effects are becoming increasingly obvious. Mass extinction, ecosystem collapse and loss of ecosystem services increasingly seem inevitable.

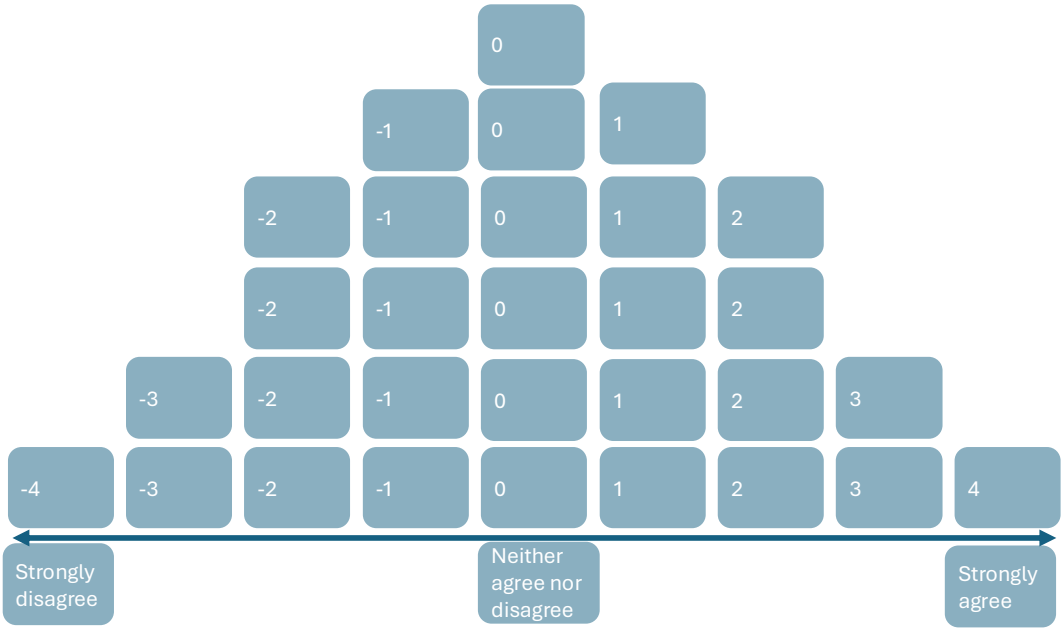
Our ability to monitor and understand these impacts is hindered by poor-quality data. There is a reduction of data integration, data holders are not collaborative and do not share their insights, and there is a lack of regional specificity in data and insights from it. Additionally, fewer people living in rural areas, means many impacts, such as unseen wildfires, go unnoticed. This poor-quality data, together with machine bias in artificial intelligence, creates a high risk of poor decision-making, as well as misuse and misunderstanding of data, resulting in increased uncertainty and confusing messaging.

This has a knock-on effect, in that public trust in, and accountability of, data and data users, are undermined. Additionally, failure to meet targets means that public trust in political integrity is undermined. Attempts to improve public relations, in this regard, incentivise greenwashing and simplistic, poorly-planned actions, such as unplanned and uninformed rewilding and afforestation that result in reduced access to the landscape, increased conflicts, acceptance of

invasive species, and putting the wrong trees in the wrong places, resulting in unintended consequences. Society largely gives up on action against climate change, allowing nature to be neglected and the effects of climate change to go unabated.

Appendix 5- Set of statements to rand and final multiple-choice questionnaire

Statements must be ranked according to personal preferences using a 9-point Likert scale (-4 to +4) and arranged in the following triangular matrix



The 30 statements classified according to their adherence to values and management

Theme 1: Values

1. The expansion of native woodlands to help connect native habitats together should be prioritised. Habitat maintenance
2. I appreciate the forest landscape as it allows me to build relationships with non-human others, and that creates meaning in my life. Spiritual/cultural
3. I enjoy spending time in the peatland landscape as it is a spiritual experience that makes me feel at peace. Spiritual/cultural
4. Spending time outside in nature helps my mental and physical health. Wellbeing/Cultural
5. The capacity of peatlands for carbon storage should be enhanced, whatever the cost. Regulatory
6. The economic contributions derived from natural capital such as forests, peatlands or farmland, are an important reason to protect it. Economic
7. The provisioning services of nature (e.g. timber and food production) should be the priority, because profitability is the primary objective of forestry and agriculture. provisioning/economic
8. Forests are important mostly because of the ecological processes they provide (e.g., oxygen production, carbon sequestration, flood reduction, species diversification). Regulatory

9. Being aware of the negative effects of climate change has made me value natural capital assets (e.g., forest, peatlands) more than I did before. Influence
10. I believe that if people experienced a greater sense of belonging and connection with nature, it would be easier to communicate messages around the values of nature. Communication
11. Tourism is very important for Scotland's economy and the quality of natural capital assets such as forests and peatlands need to be maintained so that tourists continue to visit. Cultural/ economic
12. Nature is valuable in and of itself, regardless of how humans interact with it/ benefit from it. non-use value/ Intrinsic value
13. Visiting the countryside makes me feel more connected to my heritage and ancestors. Cultural

Theme 2: Management

14. Actions to maintain/improve Scottish native woodland habitats (e.g. through the removal of invasive species) are of very high importance. Habitat maintenance/regulatory
15. The local community should have a say in landscape changes. Community
16. Command and control measures can be more effective in addressing climate change than carbon markets. Financial
17. Economic instruments (e.g. increased prices for natural capital goods/services) are key for reducing unsustainable behaviours. Financial
18. Wildfire preparedness needs to be prioritised (e.g. by developing a fire-resistant zone around one's land). Approach
19. The use of drought modelling is necessary to predict and plan for future consequential events such as crop failure and water reduction. Approach
20. Income from timber should be mainly reinvested into sustainable forest management Financial
21. Investing in tree species diversification is essential for forests to build their resilience against drought/floods, heatwaves and storms. Financial
22. AI can help us take the right decisions on the sustainable management of natural capital by monitoring and mapping biodiversity data. Tools
23. There should be more renewable energy infrastructure (wind farms, photo-voltaic plants) on peatland and agricultural landscapes to reduce carbon emissions. Tools
24. To provide multiple ecosystem services, forested landscapes should include a diversity of productive and non-productive tree species. Multifunctional
25. Woodlands (or forests) are made more valuable through clear cutting. Approach
26. The support of biodiversity in agricultural landscapes should consider space for woodlands, hedgerows and grassland. Multifunctional
27. Agricultural activities should focus mainly on farming. Protection of rivers, biodiversity, water etc. should not be of their concern. Utilitarian view/Multifunctional
28. Investors and managers need to communicate more closely to work towards sustainable land management. Communication
29. The opinions of experts rather than a diverse range of stakeholders should be mostly considered in the development of natural capital approaches. Policy

30. Community land ownership is the best option for managing the landscape in Scotland as it encourages community wealth building, income and job creation for local people. Community/private

To match the Q-sorts with the socio-economic characteristics of the participants to the workshop we asked the following questions

Please answer the following closed-ended questions

My background is in land use management

1. Yes
2. No

I work for a:

1. Private organisation
2. Public organisation

I am involved in:

1. policy making
2. decision making
3. both
4. none

I am mainly involved in:

1. managing natural assets such as peatlands, forests, water, biodiversity, etc. for their conservation
2. managing natural assets to generate provisioning services (crop, timber, recreational services, etc.)
3. managing these resources for the benefits of local communities

When I take a decision on natural capital management, this is based on economic valuation of the natural asset:

1. yes
2. no

When I take a decision on natural capital management, this is based on environmental considerations:

1. yes
2. no

When I take a decision on natural capital management, I usually use social approaches to assist this decision

1. yes
2. no

When I take a decision on natural capital management, I usually use an integrated approaches to assist this decision balancing social, economic and environmental aspects

1. yes
2. no

When I take a decision on natural capital management, I usually assess the benefits that may be generated under different scenarios

3. yes
4. no

Please state your age group (please select one only)

- 18 to 30
- 31 to 45
- 45 to 65
- Over 65
- I do not want to state my age

Please state your gender (please select one only)

- Male
- Female
- Nonbinary
- I do not want to state my gender

Please state your level of education (please select one only)

- National 5s / GCSEs (or equivalent)

- Highers / Advanced Highers / A Levels (or equivalent)
- Further Education / College
- University Degree or Postgraduate Degree
- I do not want to state

Appendix 6- Questions to get feedback on the June RESAS D5-1 workshop on using a valuation framework/toolkit

We would like to ask you for your feedback on the workshop and the tools we have proposed in this project. We would like to hear your thoughts on how well these tools help to explore a holistic range of values for natural capital in Scotland, how you think they could best be applied in different contexts.

The survey is composed of 1 multiple choice and 7 open-ended questions. It is anonymous, and you do not have to answer all the questions if you do not want to.

Please do not share personal data in open text responses (i.e. name, contact details, professional role etc) that could identify you or any other individuals. Information about how the James Hutton Institute processes personal data is available in our privacy notice, at https://www.hutton.ac.uk/terms.

- **What is your overall assessment of the workshop event?**
- (poor/fair/good/very good/excellent)
- **What did you like best about the workshop?**
- **What do you think could have been better about the workshop?**
- **How useful do you think the toolkit (as a whole, or specific tools within it) are for exploring different types of values for natural capital?**
- **Which aspects of the toolkit did you find most interesting or useful for your activities?**
- **How do you think that the toolkit could be used in practice, and to support what kinds of decision making?**
- **Please tell us your views on whether, and how, the toolkit could apply at different scales (i.e. landscape and catchment).**
- **If you responded that yes, you think that the toolkit can be applied at different scales, please tell us which of the tools you think would be most useful, and in what context?**

Thanks again for your participation. If you would like to know more about the RESAS projects underpinning the workshop, please refer to the following websites:

Bringing in participatory approaches to widen the scope of natural capital valuation

Please do get in touch with any of us if you have any further comments or questions. The D5-1 research team.

simone.martino@hutton.ac.uk ; maria.nijnik@hutton.ac.uk ; samuel.poskitt@hutton.ac.uk; katy.joyce@hutton.ac.uk ; chen.wang@hutton.ac.uk ; margaret.mckeen@hutton.ac.uk

Appendix 7 –Assessing indicators of dependency and impacts on natural capital at Glensaugh

Goal of this appendix is to propose some indicators of natural capital at Glensaugh farm and how the condition of the farm can be affected by farm management and land use change. We focus particularly on reconstructing the carbon budget and assessing how the net sequestration of the farm can change under different land use scenarios.

Land use

We build figures on carbon emissions at Glensaugh farm referring to some farm management facts (e.g., land use, livestock, use of fertilisers and energy, etc.) and environmental characteristics of soil investigated for Scotland such as water erosivity and carbon sequestration.

Excluding urban area (3.03 ha) and freshwater (5.86 ha), Glensaugh has 1004.77 ha of land dedicated to farming classified as per Table 1.

Table 1: Area of different land uses at Glensaugh farm (source: Land Cover Map 2023)

land use	**ha**
improved grassland	411.18
heather/heather grassland	319.87
acidic grassland	236.92
forestry and woodlands	36.8
freshwater	5.86
urban	3.03

Livestock management

The main farming activity is grassland management for livestock rearing. Beef and part of the sheep stock necessitate of improved grassland, while hill sheep and deer pasture on rough grassland. Published figures (2018) report 51 beef, 561 low ground sheep, 508 hill sheep and 83 deer (Ovando, 2020). These numbers are on average 20% lower than those recorded at the beginning of 2000. The 2018 livestock unit (LU) (Ovando, 2020) and stocking rate are reported in Table 2, where 1 beef, 6.67 sheep and 3.33 deer are equivalent to one LU. The stocking rate of sheep is aligned to the EU benchmark (0.7-0.8 LU/ha) (Martino et al., 2025), while that for beef and deer is much lower showing the low dependency of the livestock enterprise on land.

Table 2: Number of livestock at Glensaugh expressed as livestock unit (LU)

livestock stocking rate (2018)	**livestock unit (LU)**	**stocking rate (LU/ha)**
Beef cattle - improved grassland	51	0.45
Sheep - improved grassland	84.2	0.74
Hill sheep - rough grassland	76.2	0.16
Deer- rough grassland	24.9	0.11

Use of fertilisers

Managing grassland for producing fodder for livestock necessitates fertilisers. The farm management recorded over the last 20 years a significant decrease in the use of NPK and lime. The last published information (Ovando, 2020) reported approximately 20 tons of NPK in 2018 that was used for 411 ha of improved grassland. On average this is 48.6 kg of fertilisers per ha, lower than the average 51 kg/ha recorded in 2021 for the UK (National Statistics, 2022).

Energy use

The overall energy used in 2018 (Ovando, 2020) was provided by a mix of fuels such as propane, heating oil, red diesel, to which it is added the combustion of biomass, the consumption of electricity from the grid, and electricity production from renewables as summarised in Table 3.

Table 3: Mix of energy used at Glensaugh in 2018

fuel	**unit**	**consumption**	**kWh/unit**	**total kWh**
propane	litre	4,454.00	7.08	31,534.32
heating oil	kg	2,030.00	11.85	24,055.50
red diesel	litre	6,444.00	12.6	81,194.40
grid electricity	kWh	75,941.00	1	75,941.00
biomass	kg	7,200.00	5	36,000.00
Other renewables (wind +solar)	kwh	26,888.00	1	26,888.00
Total				**275,613.22**

This energy mix, converted in kWh (nearly 276,000 kWh) is equivalent to 274 kWh when normalised per unit of land (1ha). The farm shows to have a low dependency on energy with 12.3% of the energy demand provided by renewables and a limited use of energy per hectare compared to the average farm in Europe (987 kWh/ha) (Martino et al., 2025).

We use the above information along with biophysical properties of land in Scotland to assess the impacts of land use and livestock management at Glensaugh on soil carbon sequestration and farm carbon emissions.

Carbon sequestration

We report information on carbon sequestration per unit of land of several habitats as taken by the literature. The average content of carbon at Glensaugh is reported by Lilly et al. (2020). For the first 100 cm of soil this is equivalent to 175.5 t/ha in the area dedicated to intensive grazing; 224.14 t/ha in the area exposed to extensive grazing; and 215.6 t/ha in the area dedicated to forestry and woodlands.

As a measure of carbon sequestration, we consider a mixed forests/woodlands plantation that over a period of 30 years absorbs 1.58 tC/ha/year (Chapman et al., 2013, cited by Rees et al (2018). This figure matches the mean of the values provided by Matthew et al (2022) for broadleaves and conifers who assessed over a period of 80 years (from 2020 to 2100) a sequestration rate of 1.28 tC/ha/year for broadleaved plantations and 1.93 tC/ha/year for coniferous plantations.

The carbon sequestered of a grassland in the UK are estimated according to Janseens et al (2005) at 0.242 t C/ha/year (0.89 CO2e/ha/year). Oyesiku-Blakemore and Dondini (2022) simulated the average change in carbon sequestration of grassland in Scotland compared to the status quo finding that an improved grassland can sequester additional 0.06 t C/ha/year (0.22 tCO2e/ha/year), while an improved grassland with increase in grazing can sequester additional 0.05 t C/ha/year (0.18 tCO2e/ha/year). This figure can be higher in areas characterised by a low stocking density (West of Scotland).

Finally, we use information about emissions from peatlands reported by Rees et al (2018). Peatlands, under normal conditions, can be considered a net emitter of 2.5 t CO2e/ha/year, but this rate can be ten times higher (23.8) under eroding conditions. Conversely, peatlands restored to a good condition can be net emitters for only 0.55 t CO2e /ha/year.

Summary of the figures used in our calculations are provided in Table 4.

Table 4: Estimates of the average carbon sequestration assessed in Scotland for some of the land uses available at Glensaugh

land use	**t C/ha/year**	**reference**
grassland	0.242	Janseens et al (2005)
improved grassland (additional to the status quo)	0.06	Oyesiku-Blakemore & Dondini (2022)
peatlands (restored)	0.55	Rees et al (2018)
forestry (mix of broadleaves and conifers)	1.59	Rees et al (2018)

Carbon emissions by soil erosion

We consider the amount of carbon that is lost by erosion which is one of the most important natural sources of carbon emissions in agriculture. We take information from Rickson et al (2020) who report figures on the soil eroded in Scotland and the quantity of carbon under different land uses (Table 5).

Table 5: Soil erosion and carbon content for land uses in Scotland (Rickson et al., 2020)

land use	**mineral soil erosion (t/ha/year)**	**peat soil erosion (t/ha/year)**	**Carbon (%) in mineral soil**	**Carbon (%) peat soil**
grassland improved	3	1	7.067	33.456
grassland unimproved	2.07	0.39	13.731	29.99
rough grassland	0.75	0.39	12.755	36.197
forestry	0.6	0.13	12.453	46.711

We use this information to calculate the amount of carbon lost and CO2 emissions per unit of land (ha) (Table 6) and for the whole farm (Table 7), assuming a 13% probability of erosion (Rickson et al., 2020), corresponding to a moderate risk class of erosion at Glensaugh farm (Rickson et al., 2020).

Table 6: Unit of carbon lost and CO2e emitted by a unit of land in Scotland induced by soil erosion

land use	carbon lost (kg/ha/year) mineral soil	carbon lost (kg/ha/year) peat soil	CO2e emissions (kg/ha/year) mineral soil	CO2e emissions (kg/ha/year) peat soil
grassland improved	27.56	434.93	101.15	1,596.19
grassland unimproved	36.95	152.05	135.61	558.02
rough grassland	12.44	183.52	45.64	673.51
forestry	9.71	78.94	35.65	289.72

The land use reported in Table 6 at Glensaugh are mainly carried out in mineral soil. Therefore, we use the erosion rate for mineral soil to assess the amount of CO2e emitted by erosional processes at Glensaugh (Table 7).

Table 7: CO2e emitted at Glensaugh due to soil erosion

land use	tC/ha/year	tCO2e/ha/year	area (ha)	total CO2e - t/year
intensive grazing in improved grassland	0.028	0.101	411.180	41.591
extensive grazing in unimproved grassland	0.037	0.136	236.920	32.128
extensive grazing in rough grassland	0.012	0.046	319.870	14.599
woodland and forestry	0.010	0.036	36.800	1.312
Total			994.77	**89.630**

Carbon emissions due to energy consumption

From data reported by Ovando (2020) on CO2e emitted per unit of energy (see Table 8), the amount of CO2e/year at Glensaugh can be estimated at 73.22 tons

Table 8: Emissions of CO2e at Glensaugh from energy use in 2018

fuel	unit	consumption	CO2e emissions (kg CO2/unit)	Total tCO2e/year
propane	litre	4,454.00	1.519	6.77
heating oil	kg	2,030.00	3.178	6.45
red diesel	litre	6,444.00	2.594	16.72
grid electricity	kWh	75,941.00	0.428	32.50
biomass	kg	7,200.00	1.498	10.79

Carbon emissions due to fertilisations

The average emissions in CO2e per ton of NPK fertiliser is estimated in 6 units (Martino et al., 2025), totalling 120 tons.

Carbon emissions due to livestock management

The amount of CO2e emitted from livestock is estimated building on statistics proposed by Ovando (2020) as per Table 9.

Table 9: CO2e emissions per livestock

carbon emissions (70% enteric fermentation and 30% manure)	tCO2e/LU	Livestock unit (LU)	tCO2e/year
beef	2.68	51	136.68
sheep (hill)	1.42	84.2	119.56
sheep (lowland)	1.5	76.2	114.30
deer	1.32	24.9	32.87

Net carbon sequestration

The amount of carbon emission and sequestration is summarised in Figure 1 where it emerges how Glensaugh is a net emitter of CO2 for 315 tCO2e per year (using 2018 livestock and farm management data).

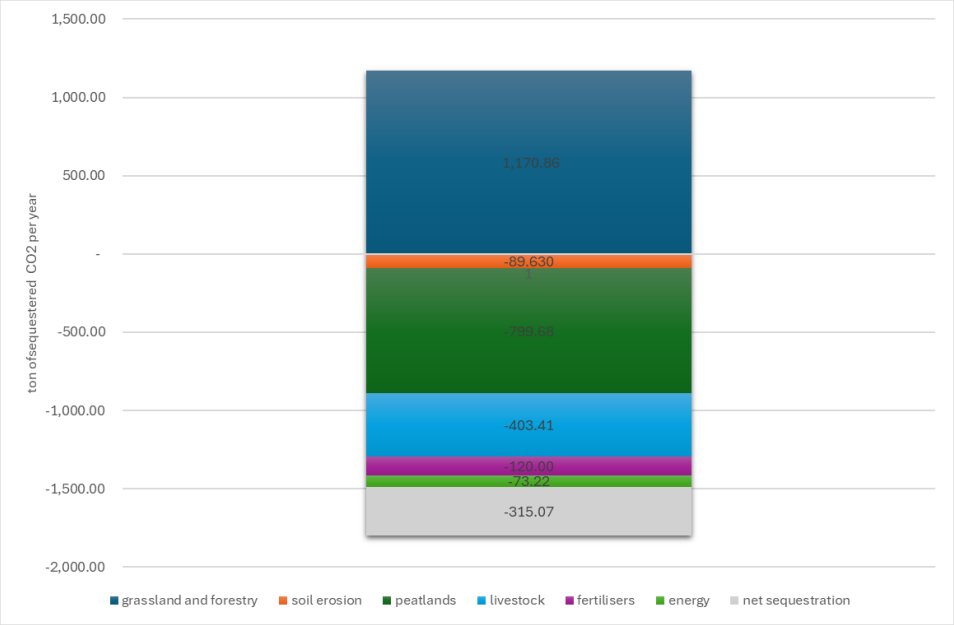


Figure 1: Emissions and sequestration of different land uses and farm management aspects at Glensaugh

According to the Figure 1, the current land use at Glensaugh shows a good capacity to sequester carbon although carbon fixation is compensated by losses coming from peatlands and the livestock enterprise. To achieve net zero, it is necessary to intervene in the future by restoring the peatlands under degradation, reducing livestock or managing differently its diet.

Summary on the impacts on some indicators of natural capital at Glensaugh

Glensaugh farm seems to be on a positive trajectory towards sustainability as proposed by the following tables summarising some indicators of dependency and impact on natural capital. The farm shows a limited use of NPK (Table 10) against a benchmark that is much higher because targets the average use of fertilises for cereals production. However, this consumption is also lower than the average UK use of fertilisers in grassland (51 kg/ka/year). The average livestock unit is also much lower than the expected European average. The amount of winter fodder produced in the farm covers nearly 20% of the livestock food requirement. A remaining 10% is externally sourced, while the remaining 70% of the metabolic requirements comes from grazing (Ovando et al., 2020). The farm is also below the benchmark for internal fodder production per livestock unit compared to an average European farm. Finally, energy consumed is only 20% of that adopted by a farm operating in the arable sector, showing an important production of electricity by renewables that in the next years will be improved to make the farm fully independent from fossil fuels.

Table 10: Dependency of the Glensaugh farm system on natural capital compared to a benchmark

indicator	average	benchmark	Benchmark/reference
NPK use - kg/ha	48.67	150 (based on arable land)	EEA. 2024. Agricultural land: nitrogen balance.

indicator	average	benchmark	Benchmark/reference
livestock - unit/hectare	0.23	0.7-0.8	Eurostat. 2023. Agri-environmental indicator
fodder crop per unit of livestock - t/year/LSU	2.7	3.5	Rana, P., Tewari, S.K., Kumar, V. and Kumar, A., 2016. Floristic structure, composition and functional characteristics of home gardens in Garhwal Region, Uttarakhand, India. International Journal of Agriculture, Environment and Biotechnology, 9(6), pp.1045-1059.
energy inputs per hectare - KWh/ha	274.5	987	The annual energy use in EU open-field agriculture is at least 1431 PJ. Taking only the energy from diesel (31%) and electricity (8%) as benchmark, this is equivalent to 155 billion kWh, or 987 kWh per ha in the EU, assuming the total agricultural land is 157 million ha in Europe (Paris et al., 2022).
share of energy consumption from renewable - %	9.75	22.5	In 2022, 22.5% of the energy consumed in the EU was generated from renewable sources, according to our early estimates.

Impacts referring to the carbon emissions and sequestration are proposed at Table 11 that shows the high rates of carbon sequestration driven mainly by the vast areas dedicated to improved grassland.

Table 11: Indicators measuring positive and negative impacts of farming on natural capital

indicator	average	benchmark	benchmark reference
soil carbon sequestration CO2e t/ha/year	1.16	0.5-1	The conversion of a farm from standard to organic practices (including composting and agroforestry) can sequester 1tC/ha/year. Organic farming practices produce 28% higher soil carbon levels than non-organic farming in Northern Europe. This represents a soil carbon sequestration rate of approximately 560kg C/year (2 tCO2/yr) for each hectare of cultivated land converted to organic farming in the UK - Soil association (2009).
GHGs emissions from soil erosion - CO2e t/ha/year	0.088	0.22	Panagos et al. (2020) showed that ca. 25% of the EU land has erosion rates higher than the recommended sustainable threshold (2 t/ha/yr) and more than 6% of agricultural lands suffer from severe erosion (11 t/ha/yr). Under a sustainable threshold of 2 ton/ha/year, assuming an average content of carbon of 3%, the benchmark is 0.22tC/ha/year.

Change in net carbon sequestration under scenario planning

We assess the impact on the net carbon sequestration under land use changes and redistribution of livestock units. These changes were discussed at the Glensaugh workshop in which narrative scenarios describing national visions for changes in natural capital were contextualised to the Glensaugh farm. Here we consider only those narratives that are relevant to envision a change in land use.

Under a scenario summarising trajectory towards positive impacts for the natural capital at Glensaugh farm, it was proposed a reduction in livestock (beef and sheep) with changes from improved to rough grassland to host a bigger population of deer, and an increase in woodlands and forests in the lowlands. While the expected change (including its technical and economic feasibility) was not quantified, we propose here a variation of 10% for these variables. We have also considered that part of the peatlands (10%) can be restored to contribute to a reduction in carbon emissions. In addition, we assume the complete autonomy of the farm from fossil fuels with 100% of energy produced internally through sustainable sources. We have also assumed a linear reduction in NPK fertilisers equivalent to 10%.

Under a scenario envisaging negative changes, extensive grassland is replaced by improved grassland (+10%) with more beef and sheep (+10%) under production. We have not considered any expansion of the forested areas and no changes in the way peatlands are managed and protected. We assume that there is no improvement in the energy efficiency, and an increase of 10% in the use of NPK fertilisers.

While a third scenario based on business as usual (BAU) pathway was discussed, the envisaged changes in land use and farming were not so different from those emerging under the negative scenario. Therefore, we decided to propose only two alternatives (one positive and another negative) and compare them with the results shown in Figure 1.

Table 12 summarises the different land use and farm management aspects with respect to the current situation, while Table 13 reports a comparison of the sequestration (positive values) and emissions (negative values) of the two scenarios against the current status. Net changes are also reported to verify where improvements can be expected.

Table 12: Characteristics of the farm under the current and new scenarios

land use	**current area (ha)**	**area - positive scenarios (ha)**	**area- negative scenario (ha)**
intensive grazing in improved grassland	411.18	370.06	452.30
extensive grazing in unimproved grassland	236.92	236.92	195.80
extensive grazing in rough grassland	319.87	357.31	319.87
woodland and forestry	36.80	40.48	36.80

livestock	**current LU**	**LU-positive scenario**	**LU -negative scenario**

beef	51	46	56
low ground sheep	561	505	617
hill sheep	508	457	559
Deer	83	91	91

fertilisers	**current use (t)**	**negative scenario (t)**	**positive scenario (t)**
NPK	20	22	18

peatlands restoration current area = 319.87 ha	**Current restored area (ha)**	**negative scenario (ha)**	**positive scenario (ha)**
	0	0	31.98

energy from renewables	**current use- kWh**	**negative scenarios**	**positive scenario**
	10%	10%	100%

Table 13: Comparison of carbon emissions (t of CO2/year) between all the scenarios. Positive values means that CO2 is sequestered while negative that CO2 is emitted.

tons of CO2e/year sequestered	**grassland & forestry**	**soil erosion**	**peatlands**	**livestock**	**fertilisers**	**energy**	**net carbon sequestration**
current status	1,170.86	-89.63	-799.68	-403.41	-120	-73.22	315.07
positive scenario	1,179.39	-87.31	-791.68	-369.51	-108	0	-105.14
negative scenario	1,180.53	-88.21	-799.68	-443.58	-132	-73.22	-356.16
change from the status quo to the positive scenario	8.52	2.32	8.00	33.90	12.00	73.22	209.93
change from status quo to the negative scenario	9.66	1.42	0	-40.17	-12.00	0	-41.09

As shown in Table 13, none of the two scenarios proposed can make the farmland carbon neutral, although the positive scenario is able to generate a net reduction in carbon emissions of nearly 210 tons compared to the status quo. The highest improvement is expected in the energy sector; the second highest impact comes from livestock. Conversely, the negative scenario is pejorative compared to the status quo because of the highest impact caused by 10%

increase in livestock. Globally the net change is not so drastic with total carbon emission increasing of 41 tons with respect to the status quo.

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Appendix 8- Preliminary findings from the Q analysis of the 30 statements reported in the Appendix 5.

We provide interpretation of the level of agreement on 30 statements reported in the Appendix 5 about a range of values and management strategies for forests, peatlands and agricultural assets. We used the Q method and analysed data by the package "*qmethod"* running under R (Zabala, 2023).

Using statistical criteria (like eigenvalue >1 and explained variance >80%), the number of factors to be considered for the analysis should be seven. However, considering the difficulty of explaining the meaning of 7 factors we have selected three factors using varimax rotation and capture 66% of the total variability. The variance explained by the first factor is 25%, while 22% and 19% is the variance explained by the second and third factor, respectively. The number of Q-sorts (or participants) in each factor is 5, 5, and 3, respectively.

The varimax rotation imposes independence (no correlation) between these factors and does not distort the data's overall variance. This process allows each statement to have a high loading on only one factor, and low loadings on the others. This makes it easier to assign a clear meaning to each factor, as it now represents a specific group of variables.

The loadings measuring the correlation between each of the three extracted factors and the 13 participants are reported in the Table 1. Loadings to factor 1 are higher for the participant number 1,5,6,8,9. Loadings to factor 2 are higher for the participants 2,3,7,10,11, while participants 4,12,13 are more likely to be associated to the factor 3.

Table 1: factor loading for each participant

Participant	Factor 1	Factor 2	Factor 3
1	**0.6307643**	0.42045343	0.08362404
2	0.1692085	**0.79365536**	0.28611059
3	0.0356787	**0.87756545**	0.14929057
4	0.5510968	0.01798798	**0.58035846**
5	**0.6776066**	0.09049631	0.16283151
6	**0.6828249**	0.36502439	0.35637628
7	0.4318148	**0.63180151**	0.08738787
8	**0.6963365**	0.20818725	0.24658247
9	**0.7223411**	0.15310627	0.12172639
10	0.5137189	**0.60536223**	0.02450470
11	0.3436699	**0.48348846**	0.35177692
12	0.1832150	0.23091115	**0.92801758**
13	0.1832150	0.23091115	**0.92801758**

Note: in bold are flagged the participants who lead on the three factors

Table 2 reports the statement factor scores, calculated by standardized z-scores, that indicates a statement's relative position and importance within a specific factor. These factor scores are rounded to match the discrete values of the original distribution matrix (from -4 to +4 in our case- see Appendix 5) showing which statements lead to each factor.

Table 2: factor scores and their agreement to each factor.

Statement	Factor 1	Factor 2	Factor 3
1	2	2	1
2	1	0	0
3	-2	-1	0
4	3	2	4
5	0	-1	-2
6	2	0	3
7	-1	-2	-3
8	4	0	-1
9	0	-1	3
10	2	1	0
11	0	-1	0
12	3	1	-1
13	0	-2	-3
14	1	3	1
15	-1	2	1
16	-1	0	-2
17	0	-1	0
18	-2	1	0
18	1	0	1
20	-1	1	-2
21	2	4	2
22	-2	-3	1
23	-3	-3	-1
24	1	1	2
25	-3	-2	-1
26	1	2	2
27	-4	-2	-4
28	0	0	2
29	-1	-4	-1
30	-2	3	-2

Leading statements that distinguish each factor are reported in the Figure 1. Z-scores indicate how important a statement is to the viewpoint expressed by each statement in a factor. Scores for one factor significantly different (beyond a certain threshold, often 1.96 standard errors of difference) from their z-scores in other factors are crucial for defining the unique nature of each viewpoint. In the Figure 1, the z-scores represented by a full symbol define the statement that fully distinguish that factor.

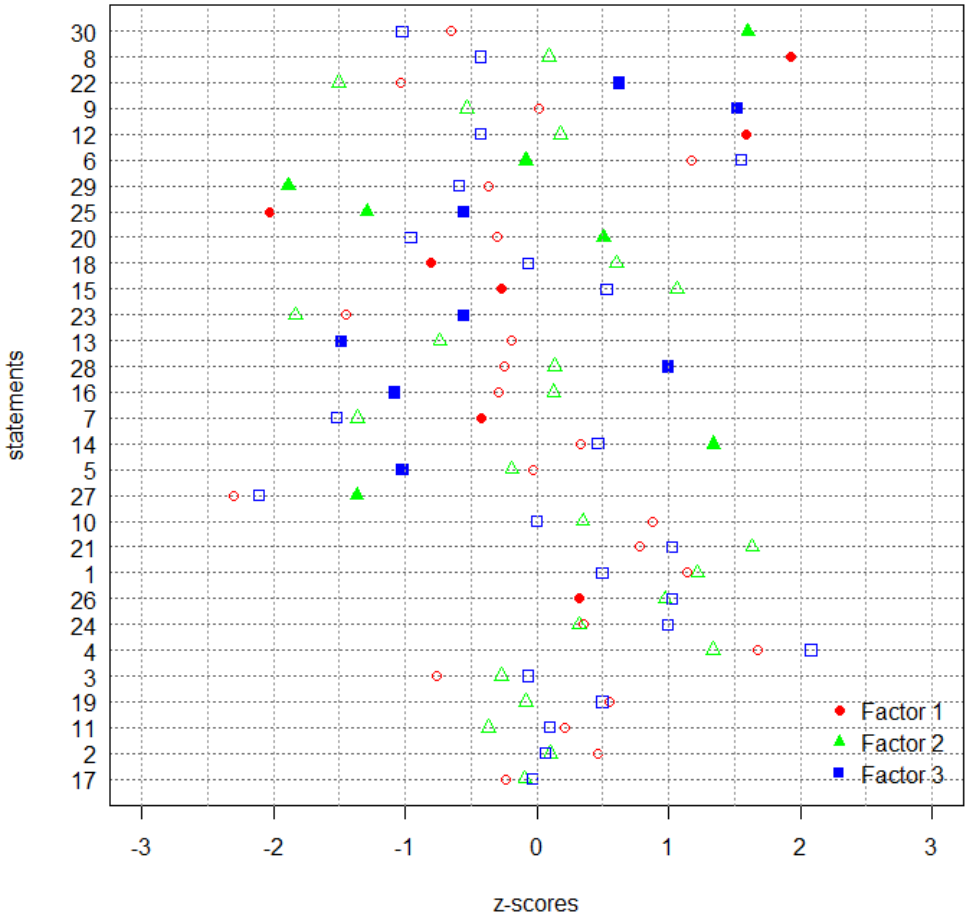

Figure 1: Plot of the z-scores for each statement. The solid symbol explains which statement distinguishes a specific factor. A positive z-score indicates that the factor's representative viewpoint generally agrees with or highly values that statement (it was placed in the "agree" end of the Q-sort grid). A negative z-score indicates that the factor's representative viewpoint generally disagrees with or highly disvalues that statement (it was placed in the "disagree" end of the Q-sort grid).

Analysing the statements according to the z score that distinguishes only for that factor, it is possible to construct a narrative description of that subjective viewpoint or perspective.

Statements that distinguish Factor 1 (positive agreement)

#8 Forests are important mostly because of the ecological processes they provide (e.g., oxygen production, carbon sequestration, flood reduction, species diversification).

#12 Nature is valuable in and of itself, regardless of how humans interact with it/ benefit from it.

#26 The support of biodiversity in agricultural landscapes should consider space for woodlands, hedgerows and grassland.

Statements that distinguish Factor 1 (negative agreement)

#7 The provisioning services of nature (e.g. timber and food production) should be the priority, because profitability is the primary objective of forestry and agriculture.

#15 The local community should have a say in landscape changes.

#18 Wildfire preparedness needs to be prioritised (e.g. by developing a fire-resistant zone around one's land).

25 Woodlands (or forests) are made more valuable through clear cutting.

Interpretation of factor 1 – "Managing NC to generate a plurality of values"

This factor is a clear expression of value plurality, with focus on a relational and intrinsic perspective of nature. Provisioning services are not a priority. Clear cutting is not a way to valorise forests and agriculture activities should not focus only on farming but on protecting habitats (rivers) and biodiversity. Outdoor recreational activity is seen as a good way to improve physical and mental health. The statements that are leading this factor emphasise the need to manage forests for the range of regulating services that they provide.

Statements that distinguish Factor 2 (positive agreement)

#14 Actions to maintain/improve Scottish native woodland habitats (e.g. through the removal of invasive species) are of very high importance.

#21 Investing in tree species diversification is essential for forests to build their resilience against drought/floods, heatwaves and storms.

#20 Income from timber should be mainly reinvested into sustainable forest management.

#30 Community land ownership is the best option for managing the landscape in Scotland as it encourages community wealth building, income and job creation for local people.

Statements that distinguish Factor 2 (negative agreement)

#29 The opinions of experts rather than a diverse range of stakeholders should be mostly considered in the development of natural capital approaches.

#27 Agricultural activities should focus mainly on farming. Protection of rivers, biodiversity, water etc. should not be of their concern.

#25 Woodlands (or forests) are made more valuable through clear cutting.

Interpretation of factor 2- Local management that emphasises nature diversification

This factor refers to the importance of investing in nature diversification and maintaining native habitats. Economic contribution from natural capital is not a motivation to protect it. Agriculture should not only focus on farming outputs but recognise a protective role towards rivers and biodiversity as key aspects deserving valorisation. To support this management, income from timber can be reinvested into sustainable management and a plurality of voices must be heard. Community land ownerships are recognised as the best option for managing the landscape. A

broad range of opinions should be considered rather than experts view only in developing natural capital approaches.

Statements that distinguish Factor 3 (positive agreement)

#6 The economic contributions derived from natural capital such as forests, peatlands or farmland, are an important reason to protect it.

#9 Being aware of the negative effects of climate change has made me value natural capital assets (e.g., forest, peatlands) more than I did before.

#28 Investors and managers need to communicate more closely to work towards sustainable land management.

#22 AI can help us take the right decisions on the sustainable management of natural capital by monitoring and mapping biodiversity data.

Statements that distinguish Factor 3 (negative agreement)

#5 The capacity of peatlands for carbon storage should be enhanced, whatever the cost.

#13 Visiting the countryside makes me feel more connected to my heritage and ancestors.

#16 Command and control measures can be more effective in addressing climate change than carbon markets.

#23 There should be more renewable energy infrastructure (wind farms, photo-voltaic plants) on peatland and agricultural landscapes to reduce carbon emissions.

#25 Woodlands (or forests) are made more valuable through clear cutting.

Interpretation of factor 3- Economic values under diversification uses of NC

This factor takes into account the value of natural capital such as peatlands and forests especially under the impact of climate change. However, there is no preference for intrinsic and relational values. No sense of connection to the heritage is perceived when visiting the countryside. The economic contributions derived from natural capital such as forests, peatlands or farmlands, are an important reason to protect it, but provisioning services should not be the only priority, and agriculture should not be only considered to produce food. Natural capital is managed for economic uses, but a single focus is not relevant. For instance, managing peatlands only for carbon sequestration is not considered a good strategy. A diversification is important and there is a certain neutral position to generate economic benefits by installing renewable energy infrastructure on peatlands and agricultural landscapes and clear-cutting forest for timber production. A better management may be supported by information technology such as AI. Economic approaches such as carbon credits are considered more important to manage natural capital than command and control measures.

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