Natural Capital Accounts:
Progress report on primary valuation studies

RESAS 1.4.1c deliverable on primary valuation studies (1.4.1ci D2)

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Glossary

Broad habitats	Habitat classification developed as part of the UK Biodiversity Action Plan, also used by the UK National Ecosystem Assessment
Choice experiment	Stated preference method in which survey respondents are presented with different bundles of environmental attributes, each taking different levels. A 'price' attribute is also included which allows willingness to pay for the environmental attribute levels to be estimated.
Ecosystem services	Natural process and the goods and services they provide which provide benefits to people
Natural asset	The stock of assets from nature e.g. trees, soil from which ecosystem services potentially flow
Natural capital	Used interchangeably with natural asset
Revealed preference	Non-market valuation methods that infer the value of environmental goods from the value of property (hedonic pricing) or cost of time and travel to recreational sites (travel cost). Also known as surrogate markets.
Stated preference	Non-market valuation methods (e.g. contingent valuation or choice experiments) that ask survey respondents their willingness to pay for changes in provision of environmental goods in hypothetical markets.
Travel cost	Revealed preference method where the value of an environmental good or service is inferred from the cost incurred by users in accessing the asset providing such good or service, usually for recreation.

1 Introduction

The purpose of this report is to provide an update on two primary valuation studies that have been undertaken by SRUC and JHI that will inform the development of natural capital accounts for the agriculture and forestry sectors.

We also report on a knowledge exchange event held in June 2017 that engaged a range of stakeholders on work within Scotland on the impact of natural capital on well-being and the economy. This included presentations on SNH's Natural Capital Asset Index, and work on natural capital accounting (RD1.4.1) and macro-economic modelling (RD1.4.2).

2 Forest valuation study

2.1 Introduction

Forests and woodland comprise around 17% of the land cover of Scotland, which represents an increase from 4 to 5% over the past century (Aspinall et al., 2011)[1]. The primary driver of afforestation over that period was timber production and was associated with intensive planting of non-native spruce species. In recent decades the focus of forest policy has shifted in recognition that forests and woodlands provide a wider set of benefits. These initially included what would be termed cultural ecosystem services with respect to landscape aesthetics (informing felling and planting practices), biodiversity and recreation. More recently, regulating services have been emphasised, in particular the role of forests in carbon sequestration and also the potential for natural flood management.

In recognition of these broader sets of ecosystem services the Office for National Statistics (ONS) has produced natural capital accounts for the UK's forest sector including timber, carbon sequestration, air filtration and recreation (Figure 1). Monetisation of these services revealed that timber removals accounted for a very small part of the value of ecosystem services at £228m in 2014. In comparison carbon sequestration was valued at £954m, air filtration (of PM_{10}) was £2.9bn and recreational visits were valued at £2.3bn. As only a selection of ecosystem services are represented in these accounts, water related services being a notable exception, it is reasonable to assume that the total benefits of forest and woodland ecosystem services in underestimated.

Work in developing natural capital accounts for the forest and woodland sector being undertaken in the SRP aims to expand on the ONS accounts by including a wider range of ecosystem services, and disaggregating the accounts on a spatial basis. The intention is to use the Natural Asset Register (RD1.4.1) to inform both the quantity and location of forest natural capital and also the flows of ecosystem services they produce.

SRUC were invited to join a Europe wide collaboration to develop and implement a primary valuation exploring the preferences of recreational users for different forest characteristics. Partner institutions are based in Austria, Czech Republic, Denmark, France, Germany, Poland, Switzerland. In addition to studies carried out in the partner countries, further samples were collected in Belarus and the Slovak Republic. The Europe wide approach provides an opportunity to explore how

[1] Aspinall, R, Green, D., Spray, C., Shimmiled, T., and Wilson, J. (2011) Chapter 19: Status and Changes in the UK Ecosystems and their Services to Society: Scotland in In: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

preferences for forest characteristics either vary or converge across different countries and different forest types. The forest valuation results will contribute to developing natural capital accounts for Scotland by provide a richer understanding of how forest characteristics contribute to recreational benefits.

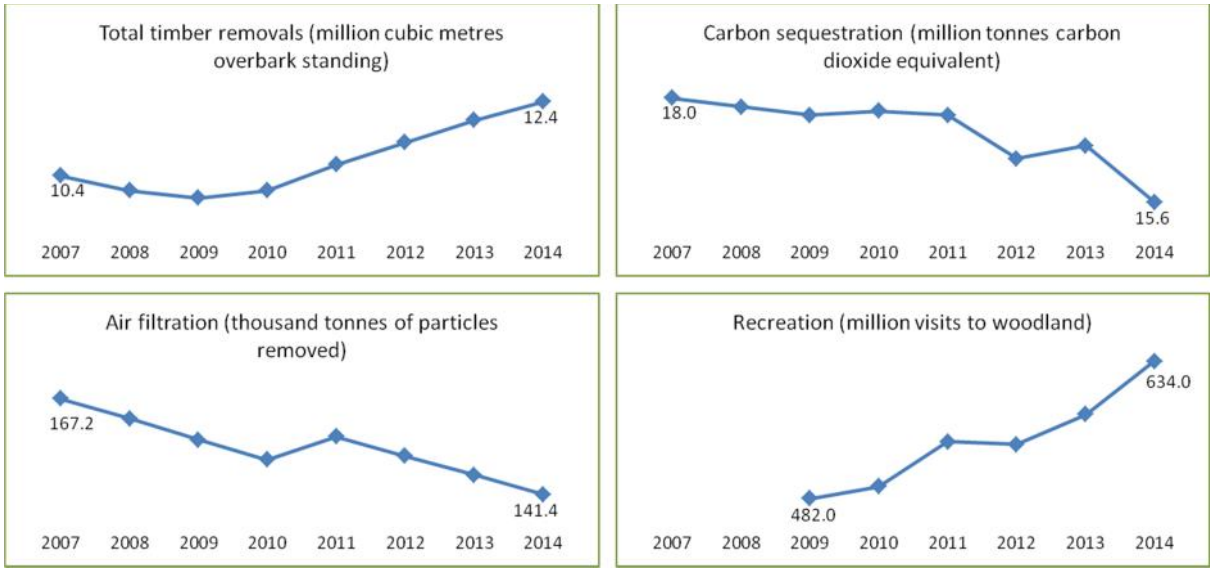

Figure 1 Woodland non-monetary ecosystem service account, 2007 to 2014, UK (Source: ONS, 2016)[2]

2.2 Methodology

2.2.1 Study design

The forest valuation study combines revealed and stated preference elements to explore how different forest characteristics impact on demand for forest recreation. Survey respondents were asked to consider their last recreational visit to a forest or woodland and to indicate how closely that forest matched the set of characteristics outlined in Table 1. Respondents were also asked a series of questions about the context of their last forest recreation visit including location (indicated using online mapping), whether visit from home or away (also indicated using online mapping), distance travelled, mode of travel, activities undertaken, number of people visited with.

The selected levels of the forest attributes were then used as the status quo option in a stated choice experiment that asked respondents whether they would be willing to travel an additional distance for recreation in forests with different characteristics, an example of one of these choices (out of 12 in total) is shown in Figure 2. By analysing the choices made over different sets of forest attributes we will be able to determine the preferences that respondents have for those attributes, i.e. do they prefer coniferous or broadleaved, younger or more mature, single aged or mixed aged, less or more deadwood (a proxy for management for biodiversity)? Note that a novel approach to the cost element of the choice experiment has been adopted. Instead of directly eliciting values by having a monetary 'price' attribute, the cost of the alternatives is specified in terms of an additional journey distance. The information collected on mode and cost of transport for the last forest visit can then be used to estimate the cost of travelling the additional distance. This can also be used to estimate travel cost models based on the last visited forest.

[2] ONS (2016) UK environmental accounts: 2016, Office for National Statistics https://www.ons.gov.uk/releases/ukenvironmentalaccounts2015

Table 1 Choice of forest characteristics

	Potential levels		
Forest type	**Coniferous** Composed mostly of coniferous tree e.g. Pine, Spruce, Fir 	**Broadleaved** Composed mostly of broadleaved tree e.g. Oak, Beech, Ash 	**Mix of both** Composed of coniferous and broadleaved tree species 
Tree height	**Recently planted** Height around 8 meters	**Growing** Height around 18 meters	**Mature** Height around 24 meters or more
Tree age structure	**Single-aged** Composed of trees that are of the same age and similar size	**Two-aged** Composed of trees that are of two age and size classes	**Multi-aged** Composed of trees of varying age and size classes
Deadwood (proxy for biodiversity)	**None** No trees left for natural decay	**Low** Few trees left for natural decay; on average wood left for decay can be found every 50 m	**Medium** Several trees left for natural decay; on average wood left for decay can be found every 25 m
Recreation facilities	**None**	**Picnic facilities** (tables and benches)	**Marked hiking trails**

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Please make the choice assuming the same context as your last visit (e.g. jogging on a week day, family visit on a weekend, etc.)

Which of these three forests would you visit?

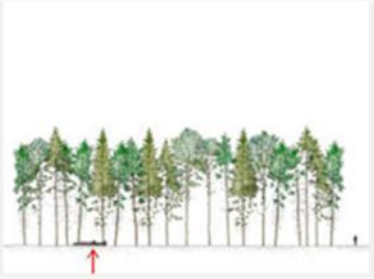
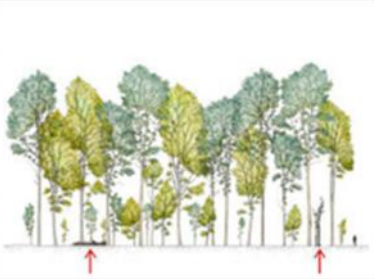
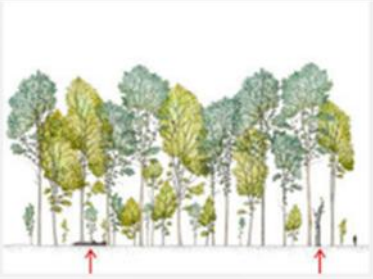
Forest A	Forest B	Last visited forest
Mix of 3 tree species (2 coniferous and 1 broadleaved), tallest trees 18 m, single-aged, low amount of trees left for natural decay	Mix of 2 broadleaved tree species, tallest trees 24 m, multi-aged, medium amount of trees left for natural decay	Mix of 2 broadleaved tree species, tallest trees 24 m, multi-aged, medium amount of trees left for natural decay
		
None 	Marked trails 	Marked trails 
One way distance 4 miles	One way distance 2 miles	One way distance 0-2 miles
○	○	○

Figure 2 Example forest recreation choice set

2.2.2 Sampling

The survey was conducted throughout February and March 2017 as an online survey. The target sample for Scotland was 1000 people who had made at least one recreational visit to a forest or woodland during the past 12 months. The sample also used a quota intended to be representative of the Scottish population based on size of settlement (e.g. village, town or city), age, education and gender. Across the different countries the following sample sizes were obtained:

Austria	1070
Belarus	606
Czech Republic	988
Denmark	1053
France	1161
Germany	1133
Poland	1068
Scotland	1122
Slovak Republic	977
Switzerland	1061

The Scottish sample indicated that they visited forest locations throughout Scotland, either making these visits from their homes or whilst away from home, for example whilst on a weekend break or holiday (Figure 3). Although there are clearly some errors in the mapping exercise (forests visited in

the sea) these should not affect the choice experiment analysis. Figure 3 also maps the location of both broadleaved and coniferous forests in Scotland.

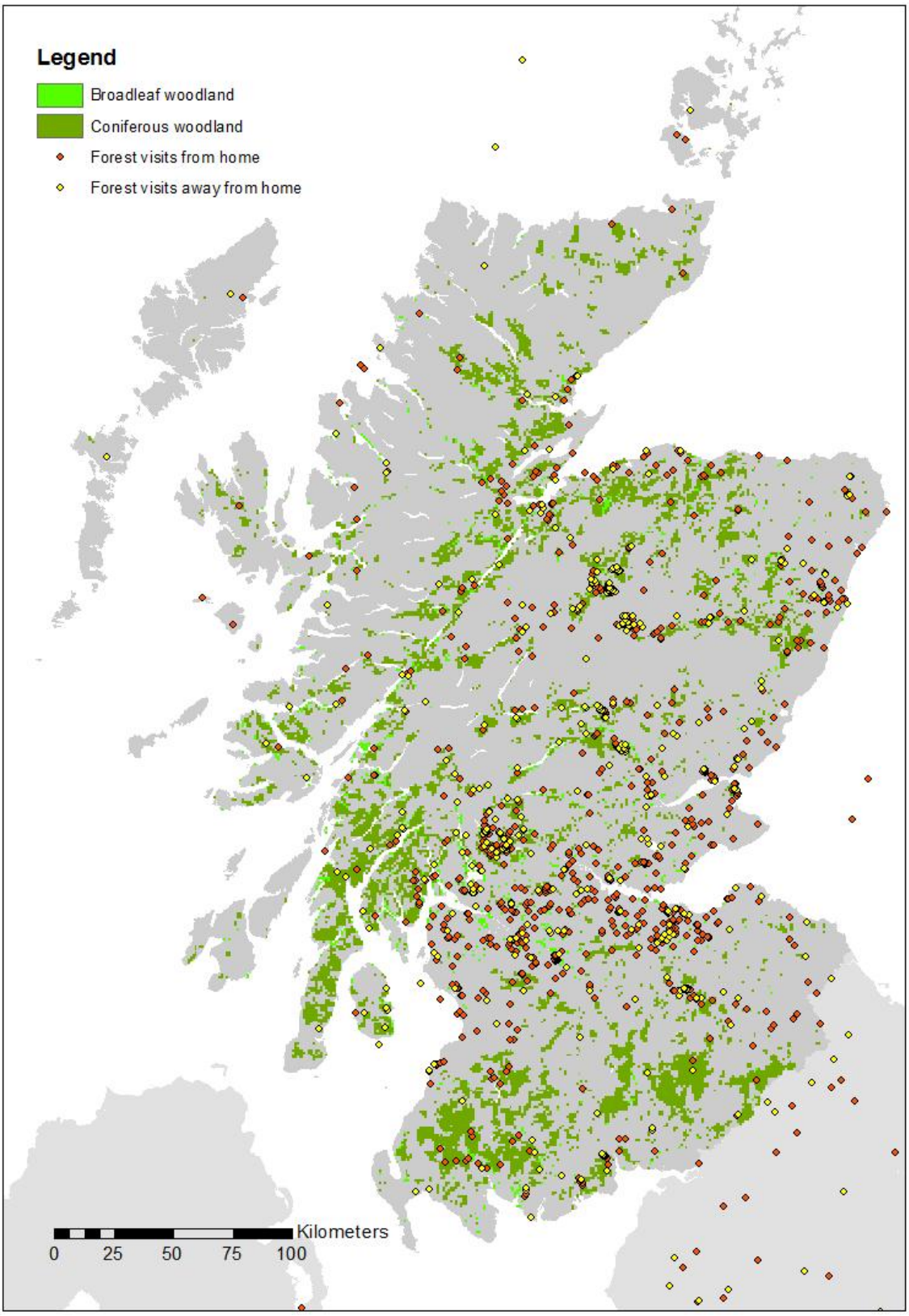


Figure 3 Forest recreation visit locations and forest habitat types (forest habitat data: CEH Land Cover Map 2007)

Some interesting patterns can be observed from the locations of forest visits:

- Key forest sites in the Loch Lomond and Trossachs and Cairngorms National Parks such as the Queen Elizabeth Forest Park (LLTNP) and Glenmore Forest Park (CNP) show high visit numbers.
- Sites with high recreation potential such as Glentress and Innerleithen in the Borders have high numbers.
- There are a large number of visits to area less associated with forests and woodlands around populated areas, particularly in the central belt. This suggests that small, local, woodland patches may be important for some recreational users.
- Larger, more remote forest areas such as Argyll and Galloway have relatively fewer recreational visits.

2.3 Preliminary results

Analysis of the survey results is currently underway with a focus on refining the appropriate econometric models across all the samples the initial priority. Nation specific models will then be estimated. The initial analysis of the choice experiment produced the results summarised in **Error! Reference source not found.** for the Scotland and combined samples[3]. As the different attributes are measured in different units the coefficient values cannot be directly compared across attributes (e.g. species mix vs. tree height) but a number of observations can be made.

Table 2 Summary results for the forest recreation survey – Scotland and combined model

Attribute		Scotland	Combined
Alternative Specific Constant - last visited forest		**1.17**	**1.03**
Distance (10 km)		**-0.07**	**-0.11**
Species mix	Monoculture broadleaf vs. monoculture coniferous	-0.01	**-0.10**
	2 species coniferous vs. monoculture coniferous	-0.06	-0.01
	2 species broadleaf vs. monoculture coniferous	**0.34**	**0.13**
	2 species mixed vs. monoculture coniferous	**0.20**	**0.21**
	3 species mixed vs. monoculture coniferous	**0.30**	**0.29**
	4 species mixed vs. monoculture coniferous	**0.69**	**0.56**
Tree height	Tree height 18 vs. 8 m	-0.02	**0.19**
	Tree height 24 vs. 8 m	**0.67**	**0.91**
Age structure	Two-aged vs. single aged	**-0.31**	**-0.30**
	Multi-aged vs. single aged	-0.04	**-0.06**
Deadwood	Low amount of deadwood vs. no deadwood	**0.12**	**0.17**
	Medium amount of deadwood vs. no deadwood	**0.28**	**0.26**
Facilities	Picnic vs. no facilities	**0.15**	**0.09**
	Trails vs. no facilities	**0.50**	**0.44**
	Picnic and trails vs. no facilities	**0.86**	**0.67**

Significant results in bold indicating positive (blue) or negative (red) relationship with reference levels

- The positive and significant values for the alternative specific constant indicate that the last visited forest was preferred to the offered (hypothetical) alternatives.
- The negative coefficient for distance confirms that respondents prefer to travel shorter distances.

[3] A full model results table with diagnostics is presented in Appendix 1, Table A1.

- In general forests with a higher number of species (coniferous or broadleaved) are preferred to coniferous monoculture. Scottish respondents are indifferent between broadleaf and coniferous monocultures; in contrast across the whole European sample coniferous monocultures are preferred to broadleaf monoculture.
- Taller trees, indicating more mature forests, are preferred to shorter, younger trees. Scottish respondents were indifferent between growing (18m) and recently planted (8m) trees.
- Single aged forests were preferred to either two-aged or multi-aged forests (Scottish respondents were indifferent to the latter).
- Respondents preferred greater amounts of deadwood
- Visitor facilities were favoured, with stronger preferences for trails compared to picnic facilities, with a combination of facilities most preferred.

The preliminary conclusions that can be drawn from these results is that recreational users prefer more natural looking and established forests (mixed species, mature trees, with high levels of deadwood) which also have good visitor facilities. However, there remains considerable further analysis to be completed, for example relating preferences to recreational activities.

2.4 Application to natural capital accounts

The results of the forest recreation valuation survey will inform the development of natural capital accounts for Scotland in a number of ways. We will have a deeper understanding of the travel cost behaviour of recreational users that can tell us which areas of Scotland are likely to have higher forest recreation values. Together with insights on how forest management impacts of values (e.g. species mix, deadwood management) this can inform management decisions to reflect those values. The results with respect to forest height and age structure will also inform estimates of the potential flow of benefits from woodland planting projects. As forest management is seeking to address multiple objectives such as timber, carbon sequestration and cultural benefits, these results could inform where management for different objectives should be focused. For example, more intensive monoculture for timber and carbon sequestration will not provide the highest recreational benefits so could be targeted in areas where recreational demand will be lower. Alternatively, multi-benefit forestry with more varied species could be encouraged closer to centres of population.

The location of forest visits also indicates that there are important woodland recreation opportunities in areas not associated with large areas of forest cover. For example, woodland in urban and agricultural settings may be important and the benefits of woodland could be included in natural capital accounts either for those habitat types or for defined spatial units such as catchments or land holdings.

3 Agriculture valuation study

3.1 Introduction

The development of natural capital accounts for farmland areas represents one of the policy priorities in Scotland.[4] The purpose of a natural capital account in farmland areas is to provide a better understanding of the interdependencies between agricultural activities and the environment to better inform policies to maintain or improve the natural capital in farmland areas.

In Scotland, where agriculture represents about 79% of the land use (ERSA, 2016)[5], the farming sector can be responsible for good and bad impacts on the environment, depending on the intensity of agricultural practices. Agriculture can contribute to the production of public goods such as food production/security, employment, rural vitality, but it can also have negative consequences for water quality and quantity, biodiversity and habitats if not managed in an appropriate way. In this setting, policy efforts have been oriented towards providing incentives for farmers to adopt environmentally-friendly farming techniques. One increasingly used tool to achieve such goal consists of agri-environmental schemes, which allow farmers to voluntarily implement practices that are good for the environment, beyond what they are required to do by law, in exchange of monetary compensation.

To inform the design of a natural capital account for agriculture in Scotland that can help the development of more effective policies, knowledge of the benefits of environmental quality preservation in farmland areas is required. In particular, information on the monetary value that people place on environmental improvements in these settings can be highly convenient. This is because it would allow comparison of the benefits and costs of changing agricultural practices by means of the same unit of measurement (£). To gather such information, the implementation of primary valuation studies is required given that knowledge of the monetary value of environmental quality improvements is often not readily available from other sources.

For the purposes of this study, we relied on a stated preference valuation survey which was designed to obtain information on the benefits of improved environmental conditions in agricultural areas. As a case study, we elicited the north-east of Aberdeenshire, which represents an area of semi-intensive agricultural practices where there are pressures on the environment. This work was part of the EU project PROVIDE (PROVIding smart DElivery of public goods by EU agriculture and forestry; www.provide-project.eu), which focuses on identifying smarter mechanisms for the provision of public goods by agriculture and forestry in 13 EU countries.

Our work aims to contribute to previous efforts of the ONS to produce natural capital accounts for farmland areas by 2020. So far, an experimental natural capital account for UK farmland areas has

[4] Scotland has a strategy to protect and improve its natural capital. For example, the 2020 Challenge for Scotland's Biodiversity strategy document includes the outcome that the stock of natural capital is increased for the next generation. The Scotland's Biodiversity: A Route Map to 2020 identifies 'investment in natural capital' as one of the six Big Steps to deliver the 2020 Challenge. It cites the Woodland Carbon Code and the Peatland Code as examples of on-going investment in natural capital. It also mentions investment in green infrastructure. Scotland's Economic Strategy puts natural capital at the heart of economic prosperity, again specifically in relation to investment http://www.gov.scot/About/Performance/scotPerforms/indicator/naturalcapital

[5] Scottish Government Rural and Environment Science and Analytical Services division (2016). Economic Report on Scottish Agriculture

been produced. Though, this only consisted of a physical account. We aim to enrich the account structure by updating the physical figures and incorporating information on the monetary value of selected ecosystem services provided by agriculture in Scotland.

3.2 Methodology

3.2.1 The case study area

The case study area (Figure 4) was selected as part of participatory workshops carried out with stakeholders from the Scottish agriculture and forestry sector (private and public) as part of the PROVIDE project. Within Aberdeenshire, which represented the Scottish case study region in PROVIDE, the north-east was identified by stakeholders as a 'hotspot' area, with high levels of public goods' but also bads' delivery, emerging as a result of existing conflicts and mismatches between the demand and supply of public goods.

Figure 4 Agriculture valuation case study area

The agricultural sector in the area is mixed and it focuses on the production of cereals as well as on livestock farming. Despite the industry supports the creation of jobs, the production of food and sustains rural vitality, there are also trade-offs between agricultural production and environmental quality. The two main problems identified by stakeholders in this area include the existence of pressures on water quality and biodiversity.

Some agricultural practices in the area have negative effects on the water environment. Cultivating land up to river edges, straightening and deepening river channels to improve agricultural land drainage can increase river bank erosion and the inflow of soil into rivers. In addition, agriculture can contribute, together with urban sewage, to the pollution of rivers and burns. Agriculture in this area often involves the application of fertilisers and pesticides and when these reach water courses, some of which are used for drinking water, they can decrease water quality. Both increased amounts of

soil and pollution in water can negatively affect water habitats and biodiversity, including water plants, insects and fish (SEPA, 2015).[6]

Following the Water Framework Directive classification, the ecological condition of water bodies in the area could be classified on a continuum from 'bad' to 'excellent' (Figure 5). 'Bad' is associated with high degradation of the water environment, little fauna and flora, low levels of recreational activities possible and low suitability for drinking purposes without treatment. 'Excellent' indicates that the water body is close to natural conditions, almost unaffected by human activity and supports the widest range of key species (like salmon). At the moment, the Scottish Environment Protection Agency (SEPA) classifies most of rivers in the case study area as displaying either 'moderate', 'poor', or 'bad' overall condition.[7]

	Close to natural condition	Supports key species (e.g. salmon)	Supporting widest range of uses (e.g. recreation, drinking water)
Excellent	++	++	++
Good	+	+	+
Moderate	-	+	+
Poor	-	-	-
Bad	- -	- -	- -

Figure 5 Map of current water ecological condition in the case study area

Regarding the impact of agriculture on biodiversity, a widely accepted indicator of the health of farmland environments is represented by the number of farmland bird species present. Some agricultural practices can reduce the availability of food and suitable habitats for farmland birds, which include both species that are almost exclusively found in farmed environments and species that can be found also in other habitats. Farmland birds contribute to seed dispersal and predation and therefore they play a central role in sustaining the diversity and abundance of other species. They can also enhance the public's enjoyment of the outdoor environment.

At the moment, there are about 20 different farmland bird species found across north-east Aberdeenshire (Francis and Cook, 2011)[8]. Some of these have experienced a severe decline in their populations and are at risk of disappearing from the area in the future. Some have already disappeared from other parts of Scotland. The species most at risk are particularly those that depend almost exclusively on the farmland environment.

[6] SEPA (2015). The river basin management plan for the Scotland river basin district: 2015-2027. https://www.sepa.org.uk/media/163445/the-river-basin-management-plan-for-the-scotland-river-basin-district-2015-2027.pdf

[7] http://map.environment.scotland.gov.uk/seweb/map.htm?menutype=0&layers=2

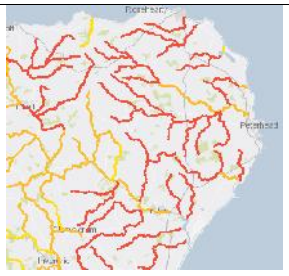
[8] Francis, I, Cook, M. (2011). The Breeding birds of North-East Scotland

3.2.2 The survey

To value the benefits that the local residents obtain from improved environmental conditions in the north-east of Aberdeenshire, we designed a choice experiment survey. Our choice experiment presented participants with combinations of different levels of improvements in water conditions and/or farmland birds species' number to be achieved by 2030 in North-East Aberdeenshire. These were presented as a result of increased management efforts in the creation of vegetated buffer strips to protect the rivers from agricultural activities, the restoration of rivers' original shape, the planting of specific seeds to sustain birds' populations or the creation of habitat (hedgerows) for birds in field margins. Increased efforts were presented as something required in the future to avoid a further degradation of the environmental conditions in the area due to climate change induced increase in pressures on water ecological conditions and farmland bird species.

The different alternatives that were created were combined into choice sets, each consisting of three options: one option, fixed across the choice sets, showed the business as usual scenario and what would occur if management efforts were not strengthened, with a resulting drop in both water quality and biodiversity levels; the other two options, varying across choice sets, displayed some sort of improvement in water ecological condition and/or farmland bird species as a result of more management efforts. Each respondent was confronted with 6 sets of alternative programmes. From each choice set the respondent was requested to pick his most preferred alternative. Every possible option (except the business as usual) was associated with a monetary cost (an increase in council tax). A summary of the attribute changes considered in the survey and an example of a choice set are provided in Table 3. An example choice set is shown in Figure 6.

Table 3 Description of attribute levels

Attribute level description	**Possible levels**						
Water ecological condition	 Business as usual		 Current situation		 Future improvement		
Farmland bird species	 15 bird species (business as usual level)		 20 bird species (current level)		 25 bird species (improved level)		
Increase in council tax	£0[a]	£5	£10	£25	£50	£75	£100

[a] business as usual level

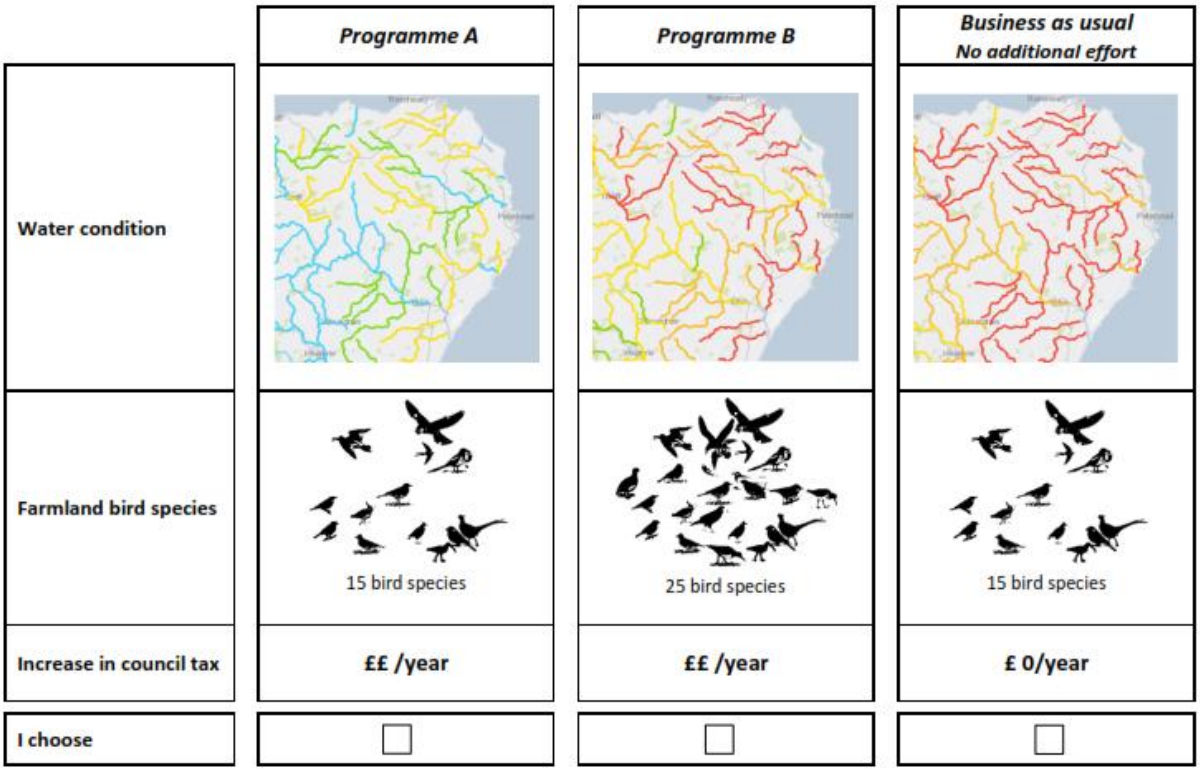


Figure 6 Example of choice card

In addition to general information about agriculture, biodiversity and water condition in North-East Aberdeenshire, and a section about the choice experiment exercise, the questionnaire also included: i) a section with follow up agreement/disagreement questions to disentangle motivations and beliefs regarding the choices of the proposed improvement programmes; and ii) a section on the participants' socio-demographic characteristics.

The survey was administered online to members of the general public in Aberdeen city and Aberdeenshire. Participants were recruited through an online panel that is managed by a market research company that adheres to quality standards set by The ESOMAR Guide to Conducting Research on the Internet (www.esomar.org). Random sampling with quotas was considered in the recruitment of panellists. A total of 313 completed surveys were collected. The sample was representative of the overall population in terms of the quotas set for gender, age and place of residence.

3.3 Results

Preliminary results in terms of respondents' preferences for environmental improvements were obtained after estimating a mixed logit model based on the preferred choices indicated by respondents in each choice card. Results, taking into account 280 respondents (after invalid surveys and protesters were eliminated) are reported in the Appendix (Table A2 and Table A3). Results suggest that individuals tend to dislike the 'business as usual' option, while they are better off when additional conservation measures are taken in the area both for water quality and for biodiversity (farmland bird species). As expected, an increase in the council tax is associated with a significant decrease in respondents' utility.

When translating these results into willingness to pay (WTP) values, by calculating the ratio between each attribute's estimated coefficient and the estimated cost parameter, it is possible to observe that individuals have a positive WTP for both improvements in water ecological condition and farmland bird species. The WTP estimates are presented in Table 4. However, differences exist

depending on the distributional assumptions made for the cost coefficient in the model. Depending on whether the cost coefficient was assumed to follow a normal or lognormal distribution, the per person median willingness to pay per year to avoid the business as usual situation and preserve current water quality in the area ranges between around £17 and £47, while for the larger improvement (improvement in water ecological condition) it ranges between around £42 and £104 per year. In the case of birds, the respondents' willingness to pay is lower, but still positive. Respondents' median per person willingness to pay per year to maintain current numbers of farmland bird species in the area (20 bird species) and avoid the business as usual situation (15 bird species) is between around £9 and £21, while it becomes between around £14 and £45 for a greater improvement (to 25 bird species).

Table 4 Willingness to pay results

Change from this situation		***to achieve this situation***	***Median WTP [a] (95% confidence interval)***	***Median WTP [b] (95% confidence interval)***
	⇨		£ 46.89 (£ 31.73 - £ 68.11) per person/year	£ 17.17 (£ 11.85 - £ 23.83) per person/ year
	⇨		£ 104.43 (£ 76.92 - £ 142.38) per person/year	£ 41.55 (£ 30.81 - £ 55.05) per person/ year
 15 bird species	⇨	 20 bird species	£ 21.37 (£ 9.11 - £ 36.97) per person/year	£ 8.74 (£ 4.18 – £ 13.93) per person/ year
 15 bird species	⇨	 25 bird species	£ 44.83 (£ 27.76 - £ 66.22) per person/year	£ 14.24 (£ 8.68 - £ 21.05) Per person/ year

[a] lognormal distribution for the cost coefficient

[b] normal distribution for the cost coefficient

Further results of the preliminary analysis (not reported in this deliverable for brevity) also suggested that WTP values are somehow sensitive to selected socio-demographic and attitudinal variables included in the survey. Just to give a few examples of the determinants explored, we focused on the role of age and place of residence. Age represents a relevant aspect, even though, it only seems to affect preferences for the farmland bird species attribute. Based on the estimated models, results indicate that elderly people appreciate the preservation of farmland bird species more than younger respondents. Regarding the effect of place of residence, preliminary findings show that there is some variability also depending on whether the respondent lives within the case study area or in other parts of Aberdeenshire outside the case study area. This is especially true for preferences for farmland bird species. In fact, results indicate that respondents living within the case study area display higher preferences for maintaining current levels of farmland bird species with respect to respondents living outside the case study area. This finding is consistent with distance decay patterns, whereby individuals living closer to the environmental good of interest display higher values (Johnston et al. 2015)[9].

3.4 Conclusions and next steps

The preliminary results of the valuation study focusing on the benefits of environmental improvements in farmland areas (north-east Aberdeenshire) suggest that the public is in favour of environmental conservation. In particular, results indicate that the preservation of water ecological conditions is of particular concern, despite it is difficult to compare preferences between water ecological conditions and farmland biodiversity due to the consideration of different changes (and magnitudes of change) for these attributes. Different factors may also determine a greater value for water quality, including concerns for health issues associated with worse water conditions in the area.

The valuation results in our study are particularly policy-relevant for the purposes of the development of a natural capital account. First, the survey took into account a realistic setting and provided an accurate description of existing environmental problems and currently employed policy mechanisms to address them (i.e. agri-environmental measures). Second, the experiment describes a specific environmental problem in a relatively geographically confined area, therefore making the problem much more tangible for people to understand and value. Third, despite the geographic specificity, the survey focuses on environmental issues that are relatively common and representative of other agricultural areas with a similar level of farming intensity in Scotland. Fourth, the survey explicitly considers spatial elements, both in the description of the attributes (especially water condition, by means of maps) and in the sampling of the population, with a balanced proportion of respondents in the sample coming from within the area as well as from outside it. Given the apparent importance of spatial factors in defining preferences, as indicated by the preliminary results, further investigating the role of these and other determinants in shaping the value of environmental improvements can be of great help. This analysis could be useful to design a spatially explicit natural capital account, which can better inform policy-making and promote more targeted action.

[9] Johnston RJ, Jarvis D, Wallmo K & Lew DK (2015) Multiscale Spatial Pattern in Nonuse Willingness to Pay: Applications to Threatened and Endangered Marine Species, *Land Economics* 91(4): 739–761. http://le.uwpress.org/content/91/4/739.full.pdf+html

The next steps in the project will therefore try to explore the potential for the development of a benefit transfer function. This consists in trying to explain the values estimated for the case study area as a function of several possible determinants with the objective of working out how values can be adjusted and transferred to different areas with similar or different characteristics. Possible factors to be further explored as determinants in the benefit transfer function, include the characteristics of the population of reference, the characteristics of the local environmental quality at the place of residence, socio-demographic factors, etc. We have already found in our preliminary analysis of results that these aspects may potentially play an important role. The idea is ultimately to explore the potential to extrapolate to other places in Scotland the information on the values of improved water ecological condition and farmland bird species numbers obtained from the primary valuation survey implemented in north-east Aberdeenshire.

4 ESCom Event: Natural capital, national performance and the economy

An ESCom Scotland event was held on 28 June 2017 that brought together different strands of work in Scotland that aim to better understand how natural capital underpins and contributes to national well-being and the economy. The event was attended by a variety of stakeholders from the research and policy communities. In this section we present a summary of that event, which has previously been published as blog articles on the SRUC[10] and ESCom[11] websites. The slide presentation on the natural capital accounting is embedded in Appendix 2.

Natural capital underpins and supports human society. But that relationship is often difficult to measure and nature may be invisible in our decision making tools and models. There is growing interest in how we can both measure changes in natural capital and develop our understanding of how those changes then impact on society. This societal impact can be considered in terms of our wellbeing and in the impact on the economy.

An ESCom event 'Natural capital, national performance and the economy' on 28 June 2017 introduced some of the different strands of work taking place in Scotland that aim to understand how natural capital contributes to our national wellbeing and the economy. Developing this understanding may help us to determine how sustainable our use of natural capital is, and where important opportunities or risks exist.

Scottish Natural Heritage has been at the forefront of natural capital assessment through the development of its Natural Capital Asset Index (NCAI) SNH's Paul Watkinson opened proceedings with a presentation on the NCAI including its recent revision. Paul explained how the index builds on the potential for Scotland's habitat to deliver a range of ecosystem services through interactions with 38 environmental indicators. Although Scotland's natural capital has declined, particularly between 1950 and the 1980s due to habitat and land use change, recent trends have shown an overall stabilisation. There remains some variation across habitats with inland and coastal waters and woodland showing improvements since 2000. However, agricultural habitats and upland habitats such as heathlands and bogs have shown declining natural capital.

[10] https://www.sruc.ac.uk/blog/sustainableecosystems/post/408/natural-capital-national-performance-and-the-economy

[11] http://escom.scot/blog/natural-capital-national-performance-and-economy

The NCAI has also been adopted as one of 55 indicators in Scotland's National Performance Framework. These indicators cover a range of economic, environmental and social outcomes and provide a broad measure of Scotland's national wellbeing.

Discussion following Paul's talk focussed on the role of expert judgement in developing the links between natural capital assets such as habitats and indicators of the ecosystem services that provide societal benefits. The NCAI is subject to revision and will respond to improvements in indicators and knowledge.

A question was also asked about whether economic values might be applied to the NCAI, this lead on to Alistair McVittie from SRUC's presentation on developing natural capital accounts for Scotland.

Alistair explained that whilst such accounts can simply include biophysical information on the stocks of natural capital assets such as habitats, the Scottish Government's Strategic Research Programme is funding research to understand how those assets deliver ecosystem services, how those services might change and how the benefits they provide can be valued. The presentation included an overview of UK level work on farmland and forest accounts by the Office of National Statistics, and noted that when considering Scotland level data there are some interesting trends in land use change that warrant further investigation. For example, CAP reform in 2014-15 prompted some counterintuitive changes in grassland cover that may affect ecosystem service benefits. Understanding the spatial aspects of such changes at appropriate scales is a key ambition of the accounting work.

Alistair also discussed current research in Scotland to value ecosystem services from both farmland and forests and woodland. This included valuation of the biodiversity and water quality impact of farmland management, and the recreational benefits of woodland. Preliminary results from the latter highlight the importance of both large forests and smaller woodland patches for recreation.

Discussion following this presentation covered the potential to look at very detailed farm data to understand the changes in management observed in regional data. This will be important to help understand how policy influences management and in turn what the impacts on ecosystem services might be.

The final presentation was by David Comerford from the Fraser of Allander Institute and covered their work on incorporating natural capital into models of the wider Scottish economy (also funded under the Strategic Research Programme). The aim of this work is to understand how changes in natural capital can have impacts on Scotland's GDP and employment, and how changes in economic activity impact upon Scotland's natural capital. David explained that natural capital inputs are implicit within the existing economic models but the challenge is to identify how changes in the quantity or quality of natural capital impact the economy particularly where prices can obscure those changes. Aims of this work include identifying the wider impacts of changes in red meat consumption including greenhouse gas emissions.

Discussion on the wider economic impacts of natural capital noted the particular difficulties of teasing out the role of natural capital. It cannot be identified as a distinct sector; instead it is pervasive throughout the economy both as an input but also playing a key role our general wellbeing with impacts on our health and productivity.

Acknowledgements

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Appendix 1 Valuation Model Results

Table A1 Multinomial logit model results for forest recreation survey – Scotland and combined model

	Scotland		Combined sample	
	Coefficient.	sign.	Coefficient	sign.
Alternative Specific Constant - last visited forest	**1.1699**	***	**1.0297**	***
Distance (10 km)	**-0.0724**	***	**-0.1079**	***
Monoculture broadleaf vs. monoculture coniferous	-0.0118		**-0.1043**	***
2 species coniferous vs. monoculture coniferous	-0.0588		-0.0088	
2 species broadleaf vs. monoculture coniferous	**0.3420**	***	**0.1298**	***
2 species mixed vs. monoculture coniferous	**0.2031**	***	**0.2082**	***
3 species mixed vs. monoculture coniferous	**0.2954**	***	**0.2900**	***
4 species mixed vs. monoculture coniferous	**0.6878**	***	**0.5630**	***
Tree height 18 vs. 8 m	-0.0233		**0.1871**	***
Tree height 24 vs. 8 m	**0.6674**	***	**0.9137**	***
Two-aged vs. single aged	**-0.3098**	***	**-0.3003**	***
Multi-aged vs. single aged	-0.0415		**-0.0582**	***
Medium vs. low amount of deadwood	**0.1247**	***	**0.1651**	***
High vs. low amount of deadwood	**0.2796**	***	**0.2608**	***
Picnic vs. no facilities	**0.1513**	***	**0.0859**	***
Trails vs. no facilities	**0.5024**	***	**0.4365**	***
Picnic and trails vs. no facilities	**0.8627**	***	**0.6709**	***
Model diagnostics				
LL at convergence	-10340.07		-100664.80	
LL at constant(s) only	-11547.27		-111734.15	
McFadden's pseudo-R^2	0.1045		0.0991	
Ben-Akiva-Lerman's pseudo-R^2	0.4511		0.4297	
AIC/*n*	1.7245		1.8077	
BIC/*n*	1.7349		1.8091	
n (observations)	12012		111395	
r (respondents)	1001		9284	
k (parameters)	17		17	

Table A2 Mixed logit model results with lognormal cost distribution

	Mean[b] (St.error)	**St. deviation[b] (St. error)**
Business as usual - alternative specific constant	-3.896*** (0.599)	3.628*** (0.513)
Water condition (current)	1.666*** (0.203)	0.995*** (0.242)
Water condition (improved)	4.208*** (0.446)	3.356*** (0.449)
Number of farmland birds (current)	0.750*** (0.169)	0.404 (0.321)
Number of farmland birds (improved)	1.473*** (0.207)	0.681* (0.354)
- Cost/100 (£)[c]	1.039*** (0.157)	1.789*** (0.135)
Model diagnostics		
LL at convergence	-1,150.939	
LL at constant(s) only	-1,717.373	
McFadden's pseudo-R^2	0.329	
Ben-Akiva-Lerman's pseudo-R^2	0.526	
AIC/n	1.3844	
BIC/n	1.4232	
n (observations)	1,680	
r (respondents)	280	
k (parameters)	12	

[a] The model was estimated using a DCE package, developed in Matlab and available at https://github.com/czaj/DCE.
[b] All coefficients except cost are assumed to be normally distributed.
[c] The (negative) cost parameter was modelled as log-normally distributed. Coefficients of the underlying normal distribution are reported. The coefficients were obtained after rescaling the cost variable by 100.

Table A3 Mixed logit model results with normal cost distribution

	Mean[b] (St.error)	**St. deviation[b] (St. error)**
Business as usual - alternative specific constant	-3.154*** (0.494)	4.047*** (0.657)
Water condition (current)	1.625*** (0.209)	1.166*** (0.265)
Water condition (improved)	4.024*** (0.425)	3.345*** (0.473)
Number of farmland birds (current)	0.776*** (0.182)	0.233 (0.416)
Number of farmland birds (improved)	1.372*** (0.228)	1.105*** (0.273)
- Cost/100 (£)[c]	4.808*** (0.611)	6.022*** (0.694)
Model diagnostics		
LL at convergence	-1,150.296	
LL at constant(s) only	-1,717.373	
McFadden's pseudo-R^2	0.330	
Ben-Akiva-Lerman's pseudo-R^2	0.525	
AIC/n	1.384	
BIC/n	1.422	
n (observations)	1,680	
r (respondents)	280	
k (parameters)	12	

[a] The model was estimated using a DCE package, developed in Matlab and available at https://github.com/czaj/DCE.

[b] All coefficients including cost are assumed to be normally distributed.

[c] The (negative) cost parameter was modelled as normally distributed. The cost coefficients were obtained after rescaling the cost variable by 100.

Appendix 2 ESCom event presentation

The following pages contain images of the slides from Alistair McVittie's presentation at the ESCom Scotland economy event (28 June 2017).

What is natural capital accounting?

SEFARI

- Natural capital is the stock of physical natural resources (biotic and abiotic)
- Accounts monitor losses and gains in our natural capital over time
- Can identify priority areas for investment and inform resourcing and management decisions
- Highlight links with economic activity and pressures on natural capital

Guidelines for natural capital accounting

SEFARI

- Defra and ONS guidance (adapted from SEEA):
  - Contribution of ecosystem goods and services generated to the wider economy
  - CICES recommended, biodiversity is an issue
  - Prioritisation may be needed:
    i. Sensitive to changes in ecosystems or at risk of irreversible losses;
    ii. Influenced through decision making and/or are particularly relevant in terms of contribution to people's wellbeing;
    iii. Measurable, based on acceptable and adequate methods.
  - Need to account for spatially explicit information
  - Information of ES values not commonly expressed in markets

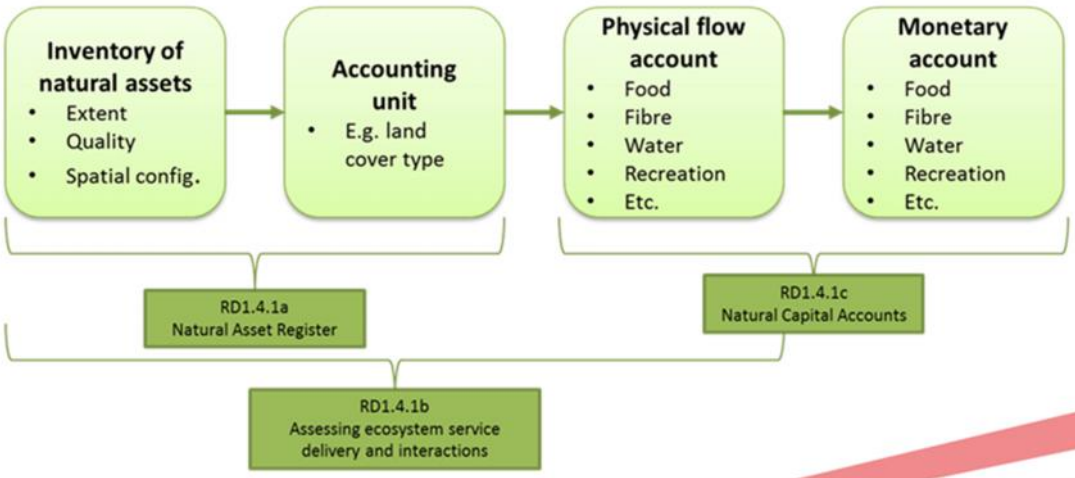
Strategic Research Programme

SEFARI

- RD1.4.1 Natural Asset Inventory and Natural Capital Accounts
- Development of a natural asset register
  - Spatially based inventory of assets
  - Identification of assets 'at risk' and include an inventory of ES flows
- Assessing ecosystem services delivery and interactions
  - Spatial modelling of natural capital assets
  - Cultural ecosystem service mapping and indicators
- Natural Capital Accounts
  - Plurality of values
  - Range of scales: national to local
  - Range of users

How does the RD1.4.1 fit with an accounting framework?

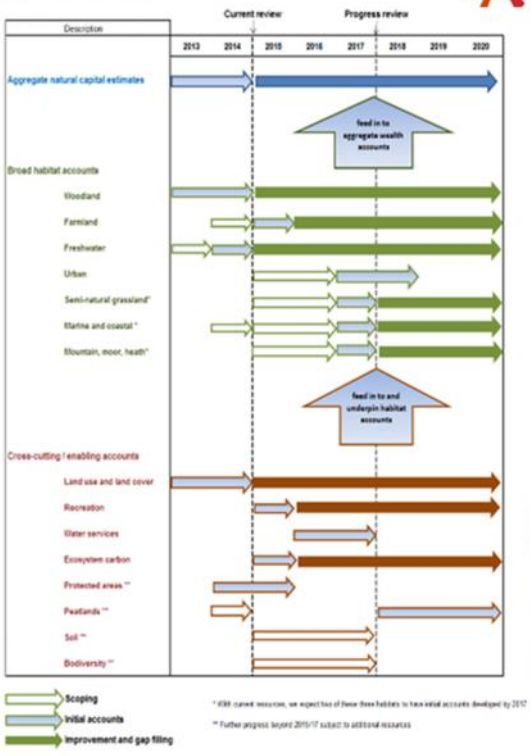
SEFARI



UK ONS NCA roadmap 2015-20

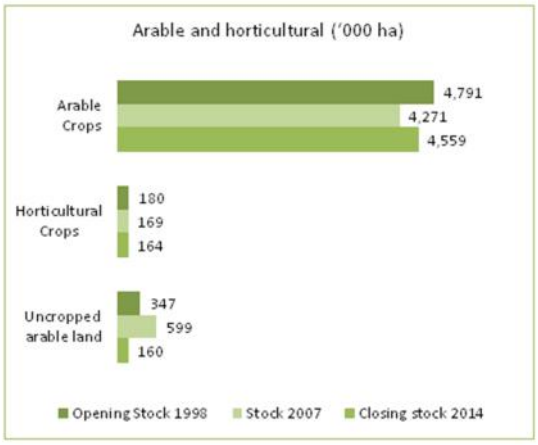
SEFARI

- Broad habitat and cross-cutting/enabling accounts
- Extent and condition only



Ecosystem Accounts for Farmland

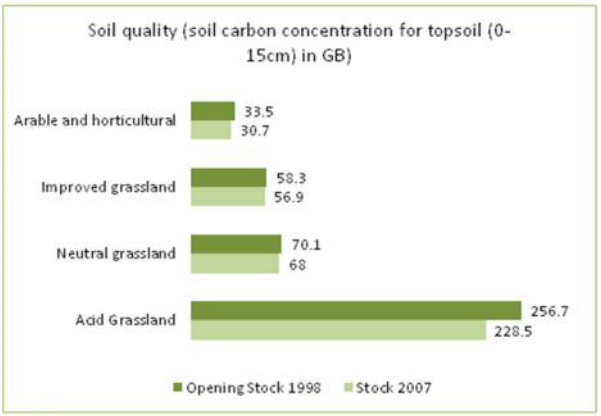
- Extent accounts
  - Arable, horticulture and grassland
  - Rough grazing
  - Linear features and other agricultural land

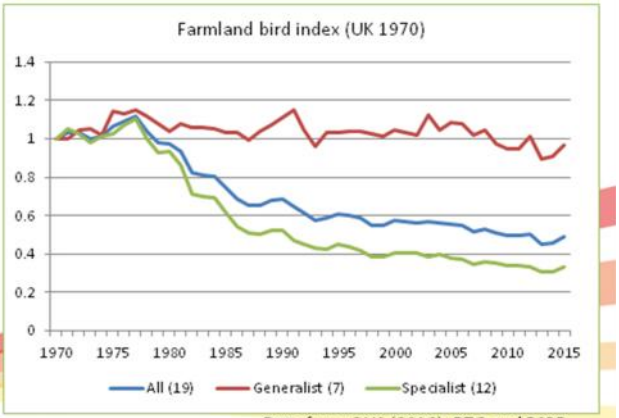


Data from ONS (2016)

Ecosystem Accounts for Farmland

- Condition accounts
  - Biodiversity: farmland birds and species richness
  - Soil quality: soil carbon concentration
  - Conservation: % of land in protected areas

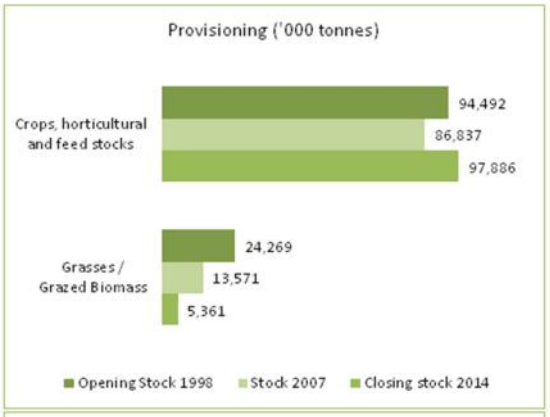


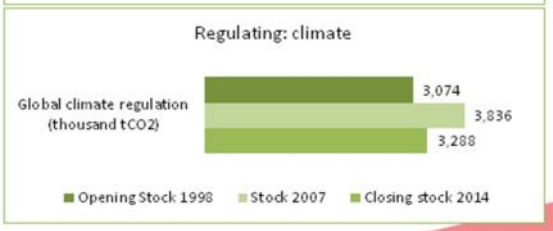


Data from ONS (2016), BTO and RSPB

Ecosystem Accounts for Farmland

- Ecosystem service accounts
  - Provisioning: crops and grasses/grazing
  - Regulating: climate regulation and waste mediation
  - Cultural: recreational visits

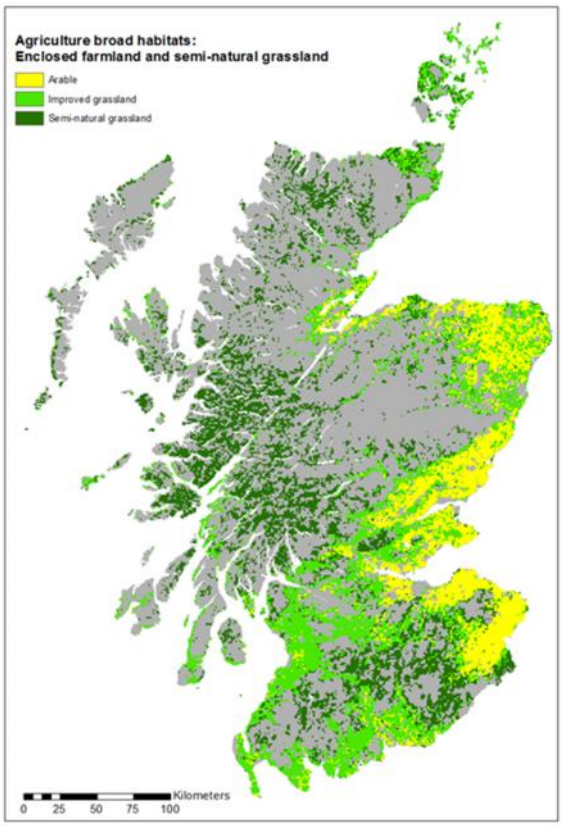




Data from ONS (2016)

Agriculture in Scotland

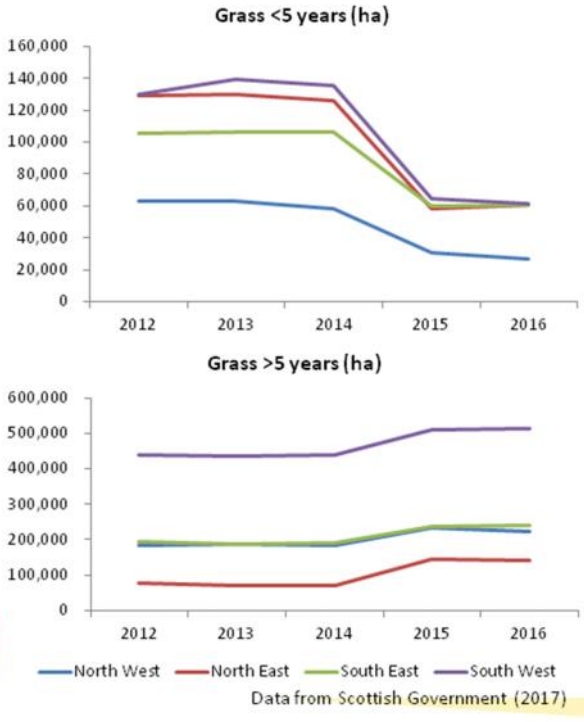
- ONS uses broad habitats
- Enclosed farmland includes arable and improved grassland
- Semi-natural includes rough grazing
- BUT
  - Improved grassland includes both temporary (rotational) and permanent grassland
  - Rough grazing also included in mountains, moors and heaths
  - Not all semi-natural is agricultural



Agriculture in Scotland

SEFARI

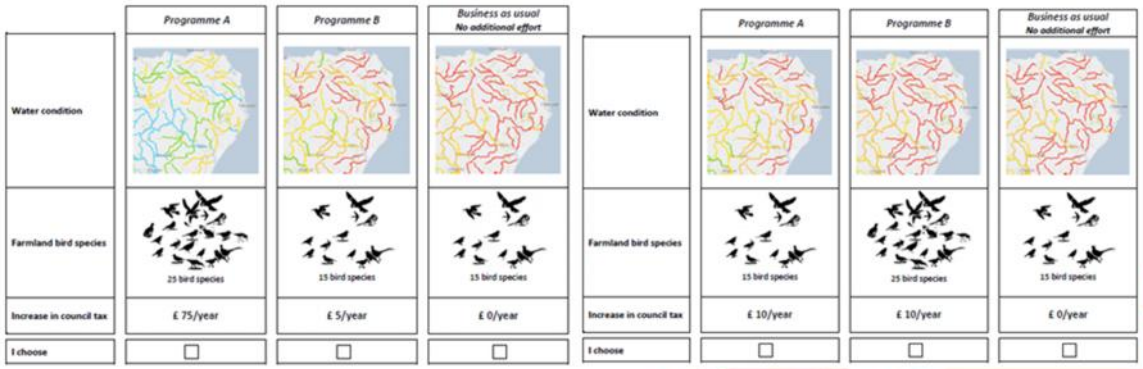
- Regional variations
- Responses to policy changes
- Are these long or short-term?
- Impacts on condition
- Impacts on ecosystem service flow



Agriculture: valuing water quality and biodiversity

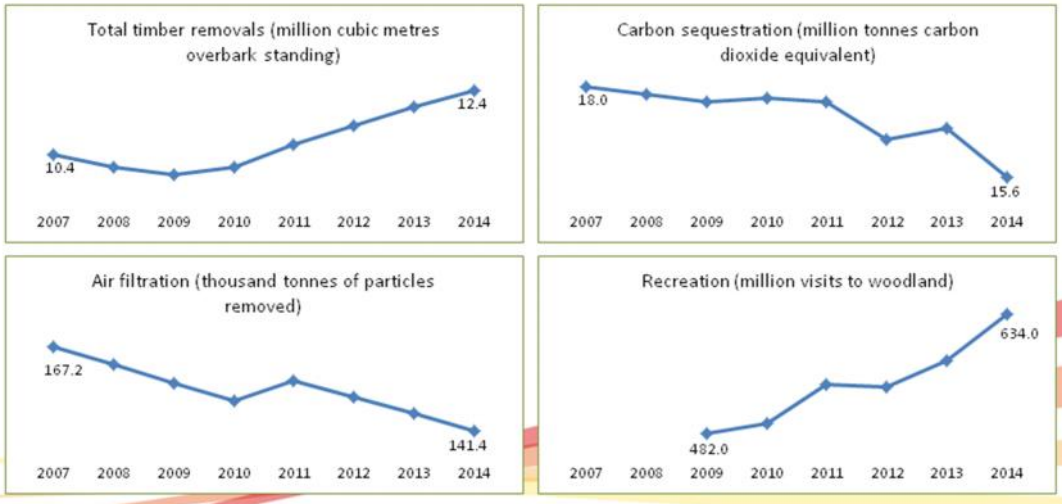
SEFARI

- Choice experiment – changing farm management to improve water quality and increase farmland birds



Forests and woodland

- ONS includes forest and woodlands in UK Environmental Accounts

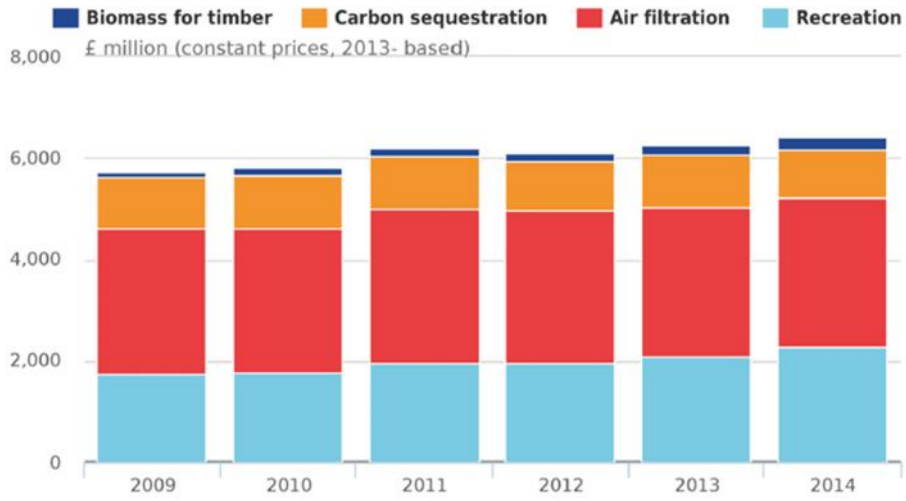


Data from ONS (2016)

Forests and woodland

Figure 22.1: Annual Value of 4 woodland ecosystem services (1)

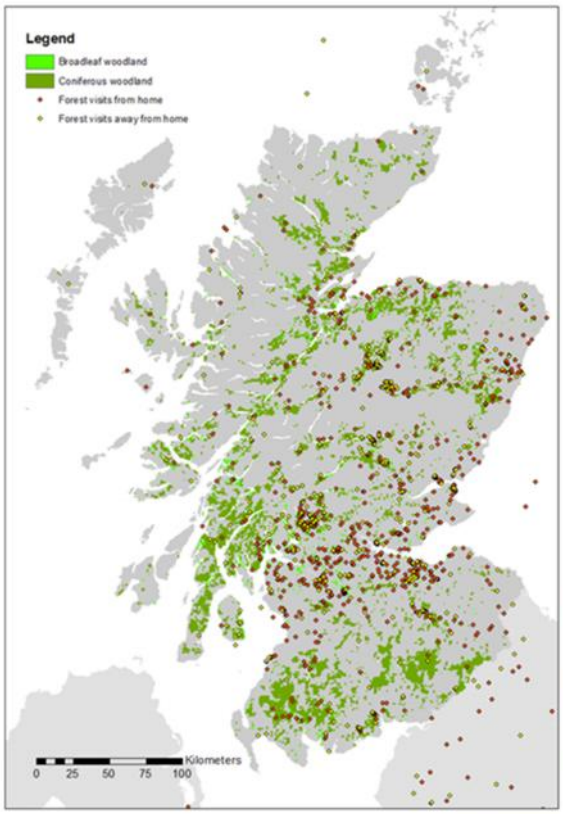
UK 2009 to 2015



Source: Department for the Environment, Food and Rural Affairs, Office for National Statistics

Forest recreation valuation

- Choice experiment considered:
  - Species mix
  - Tree height
  - Age structure
  - Deadwood (biodiversity)
  - Visitor facilities (picnic sites and trails)
- People most want :
  - Mature, multi-species broadleaved forest with high biodiversity and visitor facilities
- Implications for planting and management



Summary

SEFARI

- Extent accounts
  - Readily available but may be dynamic within broad habitats
- Condition accounts
  - Will reflect changes in management and policy
  - Mismatch with extent information
- Ecosystem service flows
  - Spatial distribution of benefits
  - Spatial configuration of habitat patches
  - Time lags linked to extent and condition

Thank you

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