Trial of the Natural Capital Protocol for land-based businesses

Den Farm
Natural Capital Assessment

March 2018

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EXECUTIVE SUMMARY

Den Farm is one of three-land based businesses participating in a trial with the objective to explore the degree to which the Natural Capital Protocol (the Protocol) is applicable and useful to land-based businesses in Scotland. Den Farm is a lowland farm with three enterprises: crop production, suckler cows and sheep.

These enterprises are dependent on natural capital (NC) assets and a range of ecosystem services (ESS). An overview of the farm's key NC assets and trends over the current tenancy is given below:

Enterprise	Asset	Trend (2016 – 2017)	
		Extent	Condition
Livestock enterprise	Temporary pasture (42 ha)	↗	↗
	Hedgerows	➔	➔
Crop production	Arable land (86 ha)	↘	↗
Other	Field margins	➔	➔
	Water (streams, 1085m)	➔	➔
"↗" = Improving/growing "➔" = stable "↘" = deteriorating/shrinking			

Natural capital dependencies

The key dependencies of Den Farm's enterprises on ecosystem services provided by the natural capital assets range from 'provisioning services' (crops and livestock production), 'regulating services' (soil quality & erosion regulation, water quality regulation, climate regulation, flood regulation, and disease & pest regulation) to 'cultural services' (cultural heritage, which includes knowledge and understanding of land and its management built up over many years).

Natural capital impacts

The key impacts of Den Farm's enterprises on ecosystem services are positive impacts on provisioning services in terms of crop and livestock production. Livestock farming is providing organic matter to the soil and improving soil biota, which is beneficial for crop production. Richard Pettit, who farms Den Farm, is further improving soil quality, such as liming the land to reduce acidity of the soil in order to increase uptake of nutrients and increase crop yield. Over time these measures will make a positive impact on regulation services, such soil quality and erosion regulation and flood regulation. This is illustrated in more detail in the case study in the report.

Den Farm's enterprises have a negative impact on climate regulation. Greenhouse gas emissions are a material impact of farming. Ploughing releases carbon to the atmosphere, fertiliser application contributes nitrous oxide and rumination of livestock generates methane (a very powerful greenhouse gas). These enterprises also have a negative impact on pollination and wild species diversity, as they are based on growing a restricted number of cultivated species.

Risks and opportunities

Risks:

- Brexit, loss of Basic Payment Scheme, resulting in a reduction in income
- Input prices may rise and become more volatile
- Increase in regulation and legislation
- Climate change and an increase in extreme weather events

Opportunities:

- Building resilience, resource efficiency, and reducing reliance on inputs. Increasing organic matter in the soil will help make the land more resilient, and mitigate against soils becoming water logged or suffering from drought. Farming practices that reduce disturbance of the soil help protect carbon, combined with practices that bring additional carbon to the soil, this will allow for carbon sequestration over time. Such practices include adding organic nutrient sources such as manure, conservation tillage (e.g.no/min-till), retaining crop residues and including cover crops in crop rotations.
- Being able to demonstrate the contribution the business is making to 'public goods', such as water quality and biodiversity is likely to become increasingly important in the future, for building sustainable brands, and for accessing public support payments.
- Creating wetland areas in small corners of the farm which are waterlogged and unproductive, to enhance biodiversity.
- Developing a set of metrics in collaboration with Crown Estate Scotland to monitor the extent and condition of the natural assets of the farm, such as soil health, water quality, hedges (shelter/mortality), carbon and biodiversity index. These can help facilitate broader conversations between landlord and tenant about future development of the farm to ensure its long term sustainability.

Actions for consideration

- Improve natural capital and ecosystem services data for Den Farm, in particular with regard to soil (e.g. organic matter, soil biota) and biodiversity. Identify a few key indicators to track natural capital e.g. soil organic matter, biodiversity abundance/diversity index.
- Apply a natural capital approach to investment and land use decisions (e.g. taking on land, wetland creation).
- Keep a watching brief on future public schemes for natural capital maintenance and enhancement.
- Engage with supply chain partners/buyers to demonstrate Den Farm's natural capital approach and identify win-wins from integrating natural capital into supply chain and marketing.

FRAME STAGE: Why?

Step 01: Get started

Crown Estate Scotland and its partners in a coalition of organisations with an interest in land management in Scotland would like to explore the degree to which the Natural Capital Protocol (the Protocol) is applicable and useful to land-based businesses in Scotland.

Natural capital refers to the natural resources (or assets) that people use and from which they gain benefit. For Den Farm, this includes its soils, water, arable and pasture land, hedges, woodland and other habitats, see Table 2. More formally, natural capital can be defined as:

"…the stock of renewable and non-renewable natural resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits or 'services' to people"[1].

Figure 1 illustrates the relationship between natural capital and the flows of benefits (which can be ecosystem services or abiotic services) which provide value to people and businesses.

[1] Natural Capital Coalition (2016) Natural Capital Protocol [online] available at https://naturalcapitalcoalition.org/protocol/.

Figure 1: Natural capital stocks, flows and values

The Natural Capital Protocol[2], produced by the Natural Capital Coalition[3], is a standardised framework for businesses to identify, measure and value their impacts and dependencies on natural capital. The framework is designed to help generate trusted, credible, and actionable information about how businesses interact with nature, or more specifically natural capital, that business managers need to inform decisions. This includes highlighting natural capital risks and opportunities for each business.

Den Farm's natural capital assets provide a range of ecosystem services, see Table 3. This framework has been adapted from the Millennium Ecosystem Assessment[4] which identifies four broad categories of ecosystem services:

[2] http://naturalcapitalcoalition.org/wp-content/uploads/2016/07/Framework_Book_2016-07-01-2.pdf

[3] http://naturalcapitalcoalition.org/

[4] Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Synthesis [online] available at https://www.millenniumassessment.org/documents/document.356.aspx.pdf

- Provisioning services; such as food supply, materials, energy, water supply, genetic resources.
- Regulating services; such as carbon sequestration and climate regulation, waste decomposition and detoxification, purification of water and air, pest and disease control.
- Cultural services; e.g. recreation, education and cultural heritage
- Supporting services; regarded as the basis for the services listed above (note: these are not separated out in the ecosystem services tables). These include services such as nutrient recycling, primary production and soil formation. These services make it possible for the ecosystems to provide services such as food supply, flood regulation, and water purification.

Den Farm is dependent on the continued supply of ecosystem services such as soil quality regulation, disease and pest regulation and local climate regulation to support crop and livestock productivity. Activities on the farm also have impacts – both positive and negative - on natural capital stocks and ecosystem services flows. Conducting a natural capital assessment of Den Farm can help to identify, measure and value the impacts and dependencies of farm activities and outputs on natural capital.

SCOPE STAGE: What?

Step 02: Define the objective

Overall project objectives

The overall aim of the project is to explore the degree to which the Natural Capital Protocol is applicable and useful to land-based businesses in Scotland through:

- completing pilot natural capital assessments for three land-based businesses, including Den Farm;
- developing businesses' understanding of natural capital and the Protocol through this pilot; and
- producing case studies to help communicate the value of reducing natural capital impacts and managing dependencies to share with the steering group and promote more broadly.

This report sets out the key findings from the natural capital assessment of Den Farm, whilst a separate Overview Report presents the findings and lessons learnt from the wider project.

Den Farm objectives

The objectives relating specifically to the Den Farm natural capital assessment are to:

- facilitate more informed decision-making in terms of land use and management, supporting enhanced environmental and economic performance and greater resilience in terms of primary production and other enterprises;
- systematically identify and assess natural capital risks and opportunities relating to the farm and how these might change in the future; and
- support the business to be better prepared and informed to secure future public payments and identify potential new revenue streams.

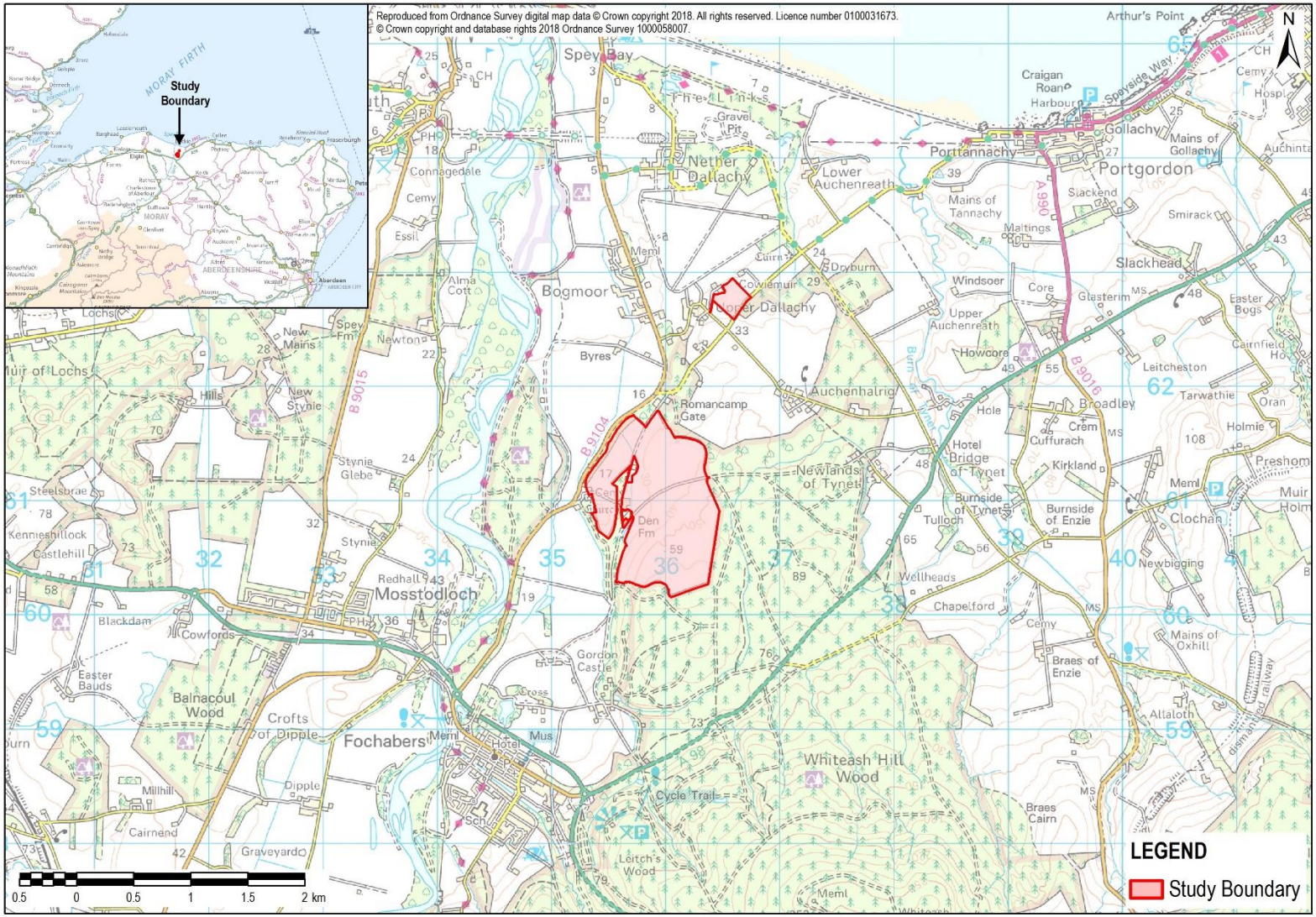
This has been done through a high level natural capital assessment of the whole farm, assessing the key natural capital impacts and dependencies of the farm's operations. In addition, a more detailed assessment of recent activities to improve soil quality was undertaken.

Step 03: Scope the assessment

Scope of farm-wide assessment

- The assessment examines the **impacts and dependencies** of everyday **on-farm activities** on natural capital stocks and the benefits they provide.
- The assessment covers the impacts and dependencies of direct operations within the farm boundaries only (see Figure 2) and does not include consideration of supply chain impacts or dependencies. However, account is taken of risks and opportunities beyond the 'farm gate' where these are relevant.
- We have assessed and valued impacts (positive and negative) from the perspectives of both the **business and society**.
- The assessment considers the impacts and dependencies of activities on Den Farm, as well the change in natural capital and ecosystem service flows over a 1-year period from the start of the current tenancy in 2016 to the present day (2017).

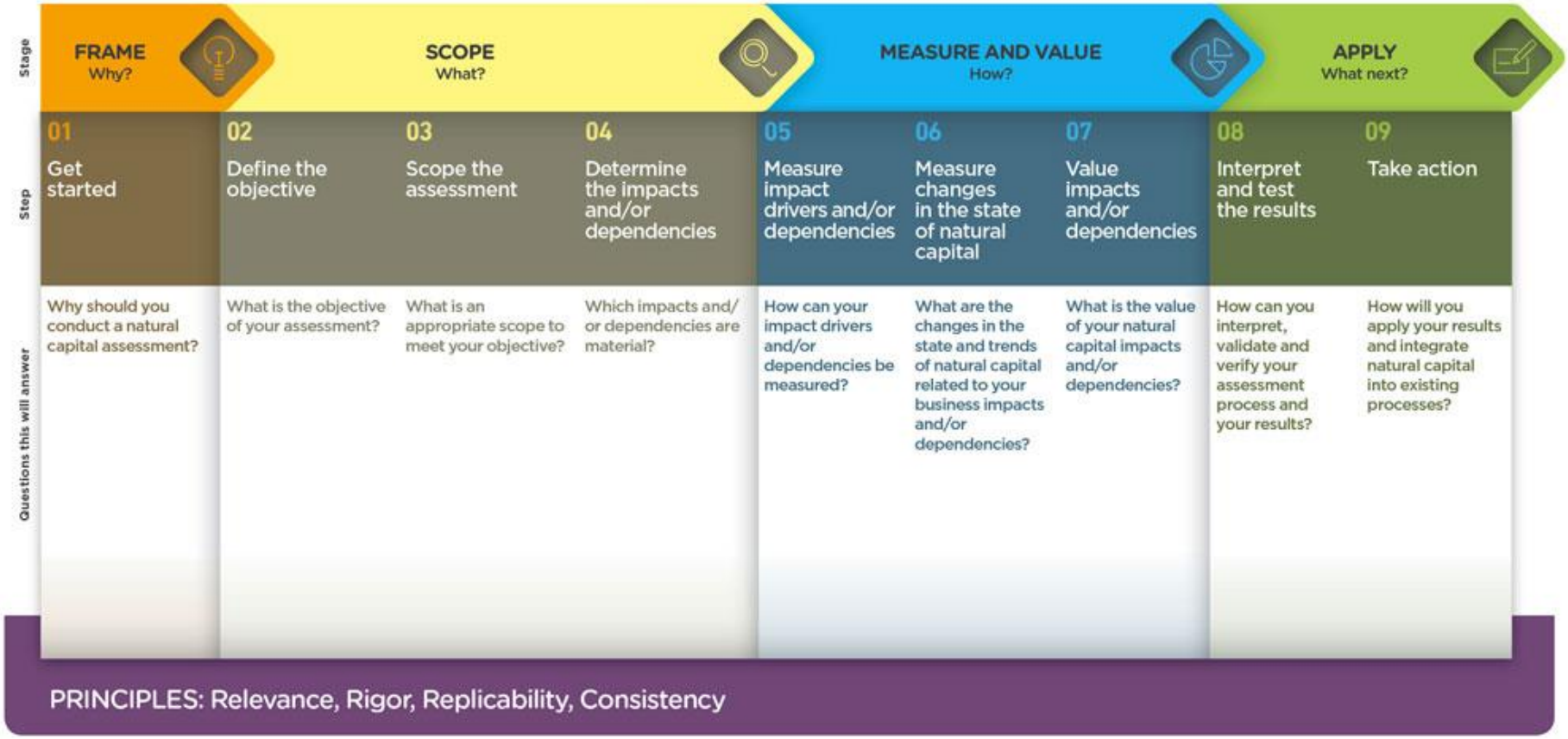
Figure 2- Map of Den Farm (red line boundary) and surrounding area



Approach

The work involved three meetings with the farmer over the period November 2017 to February 2018, a review of farm data, analysis and assessment. The work followed the steps laid out by the Protocol and this report reflects that process, illustrated in Figure 3 below.

Figure 3: Natural Capital Protocol Framework



Den Farm overview

Den Farm is owned by the Crown and comprises part of its Fochabers Estate. Crown Estate Scotland lets out the farm. Farmer Richard Pettit took on the tenancy in April 2016. Crown Estate Scotland works with its tenants to improve productivity while enhancing biodiversity. Crown Estate Scotland's wider aims are to provide opportunities for sustained employment in agriculture, forestry, sporting and tourism while giving high priority to the long term development of the Estate's community, its recreational, educational and other resources. This is balanced with the need to protect, conserve and enhance the rich natural and cultural heritage of the Fochabers Estate.

Den Farm is located near Fochabers, Moray, near the East bank of the River Spey. The total land area is 128 ha (316 acres) land of in-bye land, comprising 86 ha of arable land and 42 ha of temporary grassland (no hill and rough grazing).The land is generally flat, and the climate is relatively mild, as it is near the coast. The farm is surrounded by woodland (which is owned by nearby Gordon Castle). (See land cover map in Appendix 3).

Den Farm is a lowland farm with three enterprises, as set out in Table 1.

Table 1: Farm enterprises

Enterprise	Brief description
Arable	Spring barley (76ha), all sold for malting for whisky (Aberlour distillery, 15 miles away). 'Scotch Whisky' has EU certificate of origin certification and producers try to source locally produced barley. Winter wheat (6ha) is sold to local feed mill for animal feed. (It is grown to comply with crop diversification rules under Basic Payment Scheme 'greening')
Suckler cows	40 cows Simmental and Saler x Simmental cross on 42ha of grass, producing 40 calves. Spring calving (cattle move into shed by Christmas for calving). Calves are sold as stores and go to market (fattened elsewhere). Most calves are sold at 1 year, but sometimes Richard sells a heifer. He doesn't do any 'finishing' himself. He grows all his own silage, hay and straw. He buys in nuts (which are a by-product of the whisky distillery). 20 tonnes for cattle and calves His herd has High Health Scheme status (accredited for BVD and Johne's disease).
Sheep	150 ewes Lleyn ewes (hardy) are crossed with Suffolk ram, producing 280 lambs. Sheep overwinter outside. Lambing takes place around March. Lambs are fattened on grass (the last ones/smallest will be fed some nuts) and sold to Morrison's abattoir (dedicated Morrison supply chain).

Step 04: Determine the impacts and/or dependencies

Introduction

Every business impacts on and depends on natural capital and the ecosystem services it provides to some degree and will experience risks and/or opportunities associated with these relationships. Impacts can be negative, e.g., pollution, or positive, e.g., improved water quality.

There are many ecosystem services that flow from the different types of natural capital, not all of which will be relevant for this assessment. For farm businesses, provisioning services such as crops and livestock are highly significant while others such as noise regulation may be less so.

This step in the process aims firstly to identify the natural capital stocks that are present on Den Farm and the ecosystem services that flow from these and secondly to determine which of the impacts and dependencies upon these are most significant and worth more detailed investigation.

Natural capital assets and ecosystem services on Den Farm

Den Farm's **natural capital assets** can be viewed as a series of habitat types, set out in the form of an Asset Register in Table 2. This Asset Register lists the extent of the assets (e.g. hectares of land) and the condition, and identifies changes over time from the start of the tenancy in 2016 until now.

The land consists of 86ha of arable land and 42ha of temporary grassland. The farm has no permanent grassland or moorland. There are hedges on the farm (beech hedges planted by the estate), and woodlands surrounding the farm, providing important shelter against the prevailing winds. Mapping habitat types to ecosystem services highlights the relationship of the land to natural capital e.g. on Den Farm you can see surrounding woodlands are a key feature for local climate regulation (shelter), as well as wild species.

There are streams on the farm (of good water quality), which are tributaries to the River Spey, a Special Area of Conservation (SAC) (see Appendix 3 for maps on designated sites and water quality). Den Farm is in a Nitrate Vulnerable Zone (NVZ). Field margins were fenced off by the previous tenant funded by an agri-environment scheme to protect watercourses. Den Farm is not currently in an agri-environment scheme.

There are public access paths across Den Farm used by walkers, cyclists and horse riders. There are no scheduled monuments on the farm although there are some remnants of WW2 bunkers and a watch tower, and some Roman remains on the boundary of the farm. Although these are not defined as 'natural capital' assets, these assets may be linked with ecosystem services flows from natural capital assets, such as recreation.

The asset register shows an improvement in the condition of Den Farm's natural capital assets, particularly in relation to soil. When Richard Pettit took on the tenancy, there were problems with the land. Previously, the land had been used for growing potatoes and carrots over many years, some areas of fields were wet as drainage had been left in disrepair, and the soil suffered from compaction. There had been no livestock, so no organic matter had been added to the soil. Soil analysis showed that pH was very low, between 5 and 6, which is acidic. Nutrients might be present in the soil, but are 'locked up', because of imbalance of other nutrients in the soil.

Richard has undertaken various measures to improve the soil of this farm, such as repairing drainage, liming the soil to increase pH, adding farm yard manure and other nutrients to improve soil

structure and fertility (see the Case Study on Page 20). However, it will take several years to bring the soil in good condition. Unfortunately, there was no survey data available on biodiversity for Den Farm, nor did the soil analysis report include any information on organic matter or soil biota.

Den Farm is a member of the following Farm Assurance Schemes: Scottish Quality Crops (SQC) for cereals; and Quality Meat Scotland/Scottish Quality Beef and Lamb (SQB/QMS). His customer Morrisons (which buys his lamb) requires participation in the scheme. The assurance scheme is mainly about safety, and requires the farmer to keep records on livestock (mainly related to animal health, e.g. vaccination, medication), and on crops (fertiliser, spraying records for traceability etc). As Den Farm is in an NVZ, extra care needs to be taken that no fertiliser or sprays enter the watercourses. There are 3m field margins which prevent livestock getting too close to watercourses. These field margins are also a habitat for ground nesting birds.

Hedgerows are already fenced off, and will be maintained and improved to increase wildlife benefits. In the hedges and surrounding woodlands there is plenty of wildlife including birds and red squirrels. Over-wintered stubbles provides food for birds.

Den Farm's natural capital assets provide a range of ecosystem services. Table 3 provides an overview of the relative importance of different types of natural capital stocks on the farm in delivering ecosystem service flows (shown by coloured cells). It shows, for example, that cropland makes a strong contribution to crop production, but contributes relatively little to regulating services, such as pollination. In contrast, hedges may not supply crops, but are important for livestock production by providing shelter for sheep and lambs, whilst also providing habitat for pollinators, as well as other biodiversity.

Key dependencies and impacts

The key dependencies of Den Farm's enterprises on ecosystem services provided by Den Farm's natural capital assets range from 'provisioning services' (crops and livestock production), 'regulating services' (soil quality & erosion regulation, water quality regulation, climate regulation, flood regulation, and disease & pest regulation) to 'cultural services' (cultural heritage, which includes knowledge and understanding of land and its management built up over many years). Den Farm also depends on energy, water, and minerals sourced from natural capital elsewhere, but these are outside the scope of this study. Dependencies are reviewed in Tables 4 and 5 in the next section of this report.

The key impacts of Den Farm's enterprise are on crop and livestock production, on soil quality, and on disease and pest regulation. For Den Farm, crop yield and healthy livestock are fundamental to the success of the business. To this end, Richard undertakes a range of measures to have a positive impact on soil quality, crop yield and animal health. Den Farm's enterprises also have negative impacts, including Greenhouse gas (GHG) emissions from crop and livestock farming, which have a negative effect on climate regulation. Crop production and livestock farming enterprises also have a negative impact on pollinators and wild species diversity, as these enterprises are based on growing a restricted number of cultivated species. Impacts are reviewed in Tables 6 and 7 in the next section of this report.

Table 2: Natural capital asset register

Assets (habitat types)	Unit of measure	Start of tenancy 2016		Current status 2017		Data source	Trends (impact)
		Extent	Condition	Extent	Condition		
Enclosed farmland:							
Cropland (arable & horticultural)	ha	121	degraded	86	see case study	soil tests	improving
Temporary pasture (temporary improved grassland)	ha	5	degraded	42	see case study	soil tests	improving
Permanent pasture (permanent improved grassland)	ha	0		0			
Permanent unimproved pasture (semi-natural Grasslands)	ha	0		0			
Field margins	ha of 3m field margins	along water courses	grass species	along water courses	grass species	no survey data	not known
Hedgerows	length in meters	not known	species rich	not known	species rich	no survey data	not known
Woodland (includes farm woodlands)	ha	no woodland within tenancy, but woodlands surrounding Den Farm					
Mountains, Moorlands and Heaths	ha	0		0			
Water (Openwaters, Wetlands & Floodplains)	length in meters	1085		1085	all NVZ; 'good'	public data set	not known

Table 3: Ecosystem services

Current status 2017			ECOSYSTEM SERVICES																		
			PROVISIONING SERVICES								REGULATING SERVICES							CULTURAL SERVICES			
Assets (habitat types)	Current asset?	Trend	Crops	Livestock	Wild foods (game birds)	Wild foods (venison)	Wild foods (fish)	Water Supply	Timber	Fibre	Climate regulation	Flood regulation	Water quality regulation	Soil quality & erosion regulation	Air quality regulation	Disease & pest regulation	Pollination	Wild Species Diversity	Recreation	Education	Cultural heritage
Enclosed farmland:																					
Cropland (arable & horticultural)	yes	improving																			
Temporary pasture (temporary improved grassland)	yes	improving																			
Field margins	yes	not known																			
Hedgerows	yes	not known																			
Water (Openwaters, Wetlands & Floodplains)	yes	not known																			

Relative importance:
high
medium
low
not important

MEASURE AND VALUE STAGE: How?

Step 05: Measure impact drivers and dependencies

Step 06: Measure changes in the state of natural capital

Step 07: Value impacts and/or dependencies

This stage focused on assessing the dependencies and impacts of Den Farm activities on natural capital and ecosystem services in more detail. It starts by identifying the specific activities that are dependent on, or give rise to impacts on ecosystem services before describing the nature of these relationships and their implications both for the business itself and for others that may also benefit from the services provided. Some of the broad approaches to monetary valuation of the costs and benefits are described and are demonstrated in more detail in the case study at the end of the report.

Natural capital and ecosystem service dependencies

Table 4 highlights the extent to which the core activities on Den Farm are dependent on natural capital. Some of these are intuitive – for example, crop production is highly dependent on arable land and livestock grazing is highly dependent on temporary pasture. Dependence on other natural capital assets is less obvious – for example, hedges provide shelter for livestock.

There are also enterprises outwith the farm boundary that depend to some extent on the natural capital assets of Den Farm. For example, downstream fishing on the River Spey depends on clean water coming from the catchment; field margins at Den Farm contribute to the protection of these watercourses. Some assets are important to both on-farm and off-farm enterprises. For example, hedges provide shelter for Den Farm's livestock, as well as biodiversity that is important for shooting (shooting parties from the nearby estate have rights to shoot on the land) and recreation enterprises (not based on Den Farm, but dependent on Den Farm's assets).

Table 5 shows the dependency of enterprises on specific ecosystem services. Beyond the more obvious provisioning services of crops and livestock, this highlights that the farm depends on a number of key regulating services, including:

- local climate regulation;
- soil quality and erosion regulation; and
- disease and pest regulation.

Provisioning services

Crop production and livestock grazing are clearly highly dependent on the food provisioning services. This is due to the management of the land primarily for this purpose. These benefits are supported by a range of regulating services.

Regulating services

It is no surprise that the majority of the farm's dependencies are classified as regulating services. These are the services that regulate climate, soil quality, pest and diseases, water supply and quality, flooding, erosion and so on.

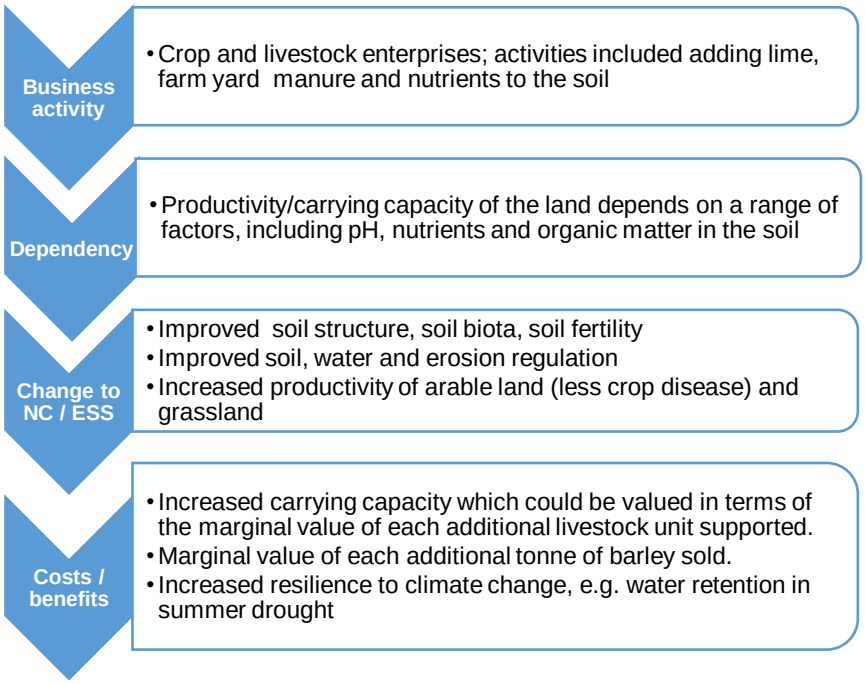
Cultural services

Cultural heritage was also identified as a 'high' dependency for Den Farm's arable operations, which are part of the local whisky supply chain. Livestock farming relies on a body of knowledge on breeding and animal health and welfare, which can be considered as the cultural and intellectual capital of the farmer.

Some locally-based businesses (particularly recreation and sporting enterprises), are also dependent on other cultural services, such as wild species diversity and recreation.

A dependency pathway has been developed for the key crop and livestock production service identified in Tables 4 and 5. The pathway describes the ways in which business activities depend on natural capital and ecosystem services and how changes in these may impact positively or negatively on the business.

Crop and livestock production ESS



This dependency pathway shows how crop and livestock production depend on the quality of the soil. At the start of the tenancy, soil analysis showed that the soil had a very low pH and was lacking organic matter. Richard has undertaken various measures to improve the soil of this farm, such as repairing drainage, liming the soil to increase pH, adding farm yard manure and other nutrients to improve soil structure and fertility. This has improved his crop and livestock production.

Table 4: Natural capital dependencies

Assets (habitat types)									
Enterprises	Enclosed farmland:								
	Cropland (arable & horticultural)	Temporary pasture (temporary improved grassland)	Permanent pasture (permanent improved grassland)	Permanent unimproved pasture (semi-natural Grasslands)	Field margins	Hedgerows	Woodland (includes farm woodlands)	Mountains, Moorlands and Heaths	Water (Openwaters, Wetlands & Floodplains)
Den Farm Enterprises			N/A	N/A			N/A	N/A	
Crop production									
Livestock Grazing									
Other enterprises									
Recreation									
Shooting									
Fishing									

Table 5: Ecosystem service dependencies

		ECOSYSTEM SERVICES																		
Enterprises	*% area of land of enterprise*	PROVISIONING SERVICES								REGULATING SERVICES							CULTURAL SERVICES			
		Crops	Livestock	Wild foods (game)	Wild foods (venison)	Wild foods (fish)	Water Supply	Timber	Fibre	Climate regulation	Flood regulation	Water quality regulation	Soil quality & erosion regulation	Air quality regulation	Disease & pest regulation	Pollination	Wild Species Diversity	Recreation	Education	Cultural heritage
Den Farm Enterprises																				
Crop production	67																			
Livestock Grazing	33																			
Other enterprises																				
Recreation	N/A																			
Fishing																				
Shooting																				

Dependency:
High
Medium
Low
No dependency

Natural capital and ecosystem service impacts

The key impacts of Den Farm's enterprises on natural capital assets are highlighted in Table 6. Given the improvements that Richard is making to the quality of the soil, his arable and livestock enterprises are having a positive impact on crop land and temporary pasture. Particularly, livestock farming is providing organic matter to the soil and improving soil biota, which is beneficial for crop production.

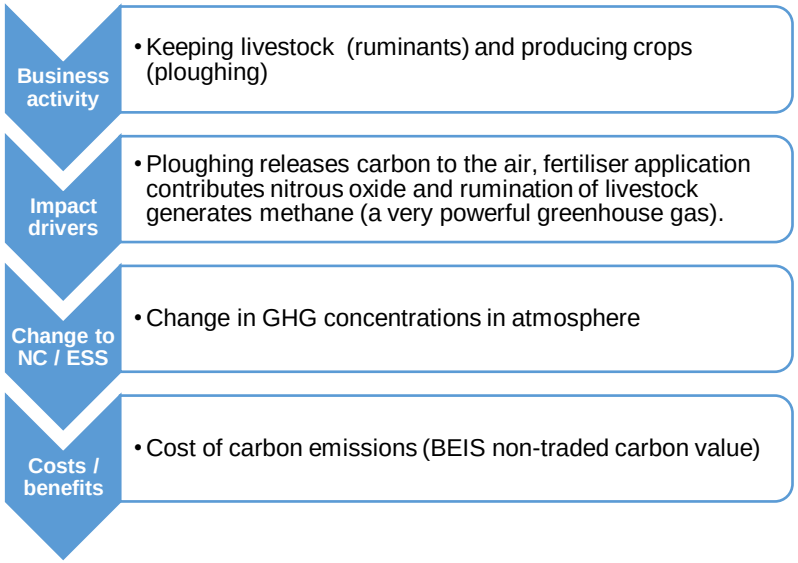
The key impacts of Den Farm's enterprises on ecosystem services are highlighted in Table 7. There are positive impacts on provisioning services in terms of crops and livestock, but negative impacts on climate regulation, pollination and wild species diversity. Greenhouse gas emissions are a material impact of farming. The crop production and livestock farming enterprises also have a negative impact on pollinators and wild species diversity, as these enterprises are based on growing a restricted number of cultivated species.

The measures taken by Richard to improve soil will over time make a positive contribution to some regulation services, such as soil quality and erosion regulation and flood regulation.

The field margins along the water courses help to prevent fertilisers and sprays going into watercourses, and therefore at Den Farm there is little risk of any pollutants entering the river. Crop production and livestock production are therefore having no or minimal negative impact on water quality regulation services.

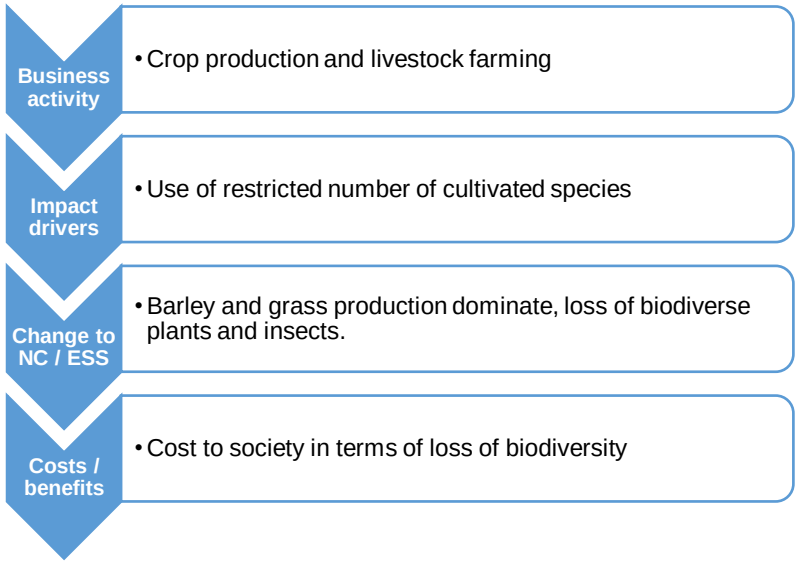
Similar to the dependency pathway, we have developed two impact pathways showing the 'logic chain' from business activity to impacts on natural capital and the costs and benefits associated with these impacts.

Climate regulation



The impact pathway above shows how crop and livestock production have a negative impact on global climate regulation. Ploughing releases carbon dioxide into the atmosphere, fertiliser application contributes nitrogen oxides and livestock rumination releases methane (a very powerful greenhouse gas) to the atmosphere.

Pollination and Wild Species Diversity



Crop production and livestock enterprises have a negative impact on pollinators and wild species diversity, as these enterprises are based on growing a restricted number of cultivated species. The field margins on the farm are grass and not species rich.

Table 6: Natural capital impacts

Enterprises	Assets (habitat types)								
	Enclosed farmland:								
	Cropland (arable & horticultural)	Temporary pasture (temporary improved grassland)	Permanent pasture (permanent improved grassland)	Permanent unimproved pasture (semi-natural Grasslands)	Field margins	Hedgerows	Woodland (includes farm woodlands)	Mountains, Moorlands and Heaths	Water (Openwaters, Wetlands & Floodplains)
Den Farm Enterprises									
Crop production									
Livestock Grazing									
			N/A	N/A			N/A	N/A	
Other enterprises									
Recreation									
Shooting									
Fishing									

Table 7: Ecosystem service impacts

ECOSYSTEM SERVICES	% area of land of enterprise	ECOSYSTEM SERVICES																		
		PROVISIONING SERVICES								REGULATING SERVICES							CULTURAL SERVICES			
		Crops	Livestock	Wild foods (game)	Wild foods (venison)	Wild foods (fish)	Water Supply	Timber	Fibre	Climate regulation	Flood regulation	Water quality regulation	Soil quality & erosion regulation	Air quality regulation	Disease & pest regulation	Pollination	Wild Species Diversity	Recreation	Education	Cultural heritage
Den Farm																				
Crop production	67																			
Livestock Grazing	33																			
Other enterprises																				
Recreation																				
Fishing						+/-														
Shooting				+/-	+/-															

Impact:	Positive	Negative
High		
Medium		
Low		
Mixed	+/-	
None		

APPLY STAGE: So what?

Step 08: Interpret and use the results

This assessment has shown the dependencies and impacts on natural capital for the arable and livestock enterprises of Den Farm. In the light of this assessment, the following risks and opportunities can be identified.

Risks

Brexit poses risks (but also opportunities) for the business. Although the Government has committed to maintaining current levels of farm support until at least 2022, it is unlikely that such a generous area-based subsidy regime is sustainable in the long term, and the loss of subsidy income is a significant risk. It is also currently unclear whether the UK can negotiate a favourable trade agreement with the European Union. Without an EU trade agreement, WTO trade rules would apply, with tariffs on lamb exports making the sheep enterprise particularly vulnerable.

To compensate for a future **reduction in income**, Richard expressed a wish to gradually increase the number of cattle and sheep to increase turnover, and to possibly expand on nearby land when it comes up. Such expansion would require additional investment. Bank borrowing would increase the financial risk; it would be safer if financed from retained profits. The carrying capacity of the existing land will be for a certain number of cattle; he does not consider increase stocking rates, as he would not be self-sufficient in feed and straw.

Input costs may rise. For example, phosphorus is a finite (limited) resource, which is likely to drive up prices (and increase price volatility) over time.

Another risk is the **increase in regulation and legislation** driven by consumer pressure and supermarkets for more sustainable products. The use of herbicides (e.g. glyphosate) is under constant review, and may limit the chemical options available for weed management. It is likely to become increasingly important to demonstrate not only best practice in animal health & welfare and crop production, but also the environmental footprint in terms of inputs (e.g. water use) and outputs (e.g. greenhouse gas emissions) is likely to be used for benchmarking suppliers.

Climate change may increase the likelihood of extreme weather events, such as excessive rainfall, storm events and drought. Ensuring resilience of the land to withstand changes in weather patterns will be important.

Opportunities

Brexit provides an opportunity for farms to produce more for the domestic market. Added value can be obtained by strengthening supply chains and investment in processing infrastructure. Brexit opens up the possibility of a new subsidy regime that is better tailored to British agriculture, as well as reducing regulations such as the ‘three crop rule’. Future policy is likely to be focused on ‘public payments for public goods’, and strongly aligned to the concept of natural capital.

Building resilience and resource efficiency will be key for an uncertain future. Liming and adding nutrients to the soil are expensive, and therefore soil analysis will need to be repeated every couple of years (including measuring soil organic matter), so that only those areas of the land are treated that really need it. New techniques are being developed to carry out soil analysis in a more cost-effective way, both high-tech (e.g. soil scanning services) and low tech (e.g. the extent a cotton rag decomposes in the soil over time).

There may be opportunities to enhance income through **reducing input costs**. For example, next year Richard is changing to ‘digestate’ fertiliser

for his grassland, which is a by-product from anaerobic digestion of the whisky distillery process and does not cost anything, saving approximately £6,000 on input costs for his grassland. This would move Den Farm a step closer towards a circular system, i.e. the crops are fertilised by livestock manure, the barley is used for producing whisky, and the residual from the whisky distillery process is put back on the grassland for grazing livestock.

Further **increasing organic matter in the soil** will make the land more resilient, and mitigate against soils becoming water logged or suffering from drought. Farming practices that reduce disturbance of the soil help protect carbon, combined with practices that bring additional carbon to the soil, this will allow for carbon sequestration over time. Such practices include conservation tillage (e.g.no/min-till), retaining crop residues, including cover crops in crop rotations, and adding organic nutrient sources such as manure. Explicit targets for soil quality could incentivise tenants to aim for gains in quality measures.

Being able to **demonstrate the contribution** the business is making **to 'public goods'**, such as water quality and biodiversity is likely to become increasingly important in the future. This would help the supply chain build sustainable brands, and may become a requirement for accessing public support payments, such as agri-environment schemes. Den Farm already has 3-metre fenced-off margins to protect water courses from livestock and run-off. There are hedges on and woodlands around the farm which are a habitat for wildlife. It might be worth asking a local conservation organisation to carry out a biodiversity survey, to gain a better understanding of what species are on the farm.

There are some small corner areas (about 1 hectare of grassland) which are always wet, and there may be an opportunity to create a small wetland. Rather than spending money on trying to make an unproductive area more productive, it might better to create a wildlife area which would **enhance the biodiversity** on the farm. Grants may be(come) available to accommodate this.

There is an opportunity to **develop a set of metrics for monitoring the natural assets** of Den Farm over time, which would:

- Record the extent and the condition of the natural assets of the farm, such as soil health, water quality, hedges (shelter/mortality), carbon, and biodiversity index.
- Review these metrics as part of the tenancy review, and record the improvement in extent and condition (or deteriorations, if any) of the natural capital assets on the farm, and any investments made. This can help facilitate broader conversations between landlord and tenant about future developments of the farm to ensure its long term sustainability.

Step 09: Take action

Actions for consideration:

- Improve natural capital and ecosystem services data for Den Farm, in particular with regards to soil (e.g. organic matter, soil biota) and biodiversity.
- Identify a few key indicators to track natural capital e.g. soil organic matter, biodiversity abundance/diversity index.
- Apply a natural capital approach into investment and land use decisions (e.g. taking on land, wetland creation).
- Keep a watching brief on future public schemes for natural capital maintenance and enhancement.
- Engage with supply chain partners/buyers to demonstrate Den Farm's natural capital approach and identify win-wins from integrating natural capital into supply chain and marketing.

CASE STUDY – Improving soil

This case study applies the Natural Capital Protocol to a practical example.

FRAME STAGE: Why?

Step 01: Get started

When farmer Richard Pettit took over Den Farm in 2016, he realised the soil of this 129ha farm was degraded and suffering from compaction, due to:

- Drainage in disrepair
- Mono-cropping during previous tenancy
- Lack of soil organic matter
- Low soil pH (acid soil) preventing the uptake of soil nutrients

Richard undertook a variety of measures to improve soil condition, in order to improve crop yield, breed/produce healthy livestock, and increase the resilience of his business.

SCOPE STAGE: What?

Step 02: Define the objective

The objective of this case study is to understand what impact Richard's activities to improve soil health have had on natural capital, as well as providing a high level cost/benefit analysis (incorporating financial costs and natural capital costs/benefits).

Step 03: Scope the assessment

This case study assesses the impacts of improving soil condition to increase productivity, including:

- drainage repairs
- adding lime to reduce acidity
- applying farm yard manure to increase organic matter
- applying other fertilisers and trace elements based on soil analysis

Step 04: Determine the impacts

The material impacts of arable and livestock enterprises are on crop production, livestock production, climate regulation (greenhouse gas emissions), soil quality, disease and pest regulation, and wild species diversity.

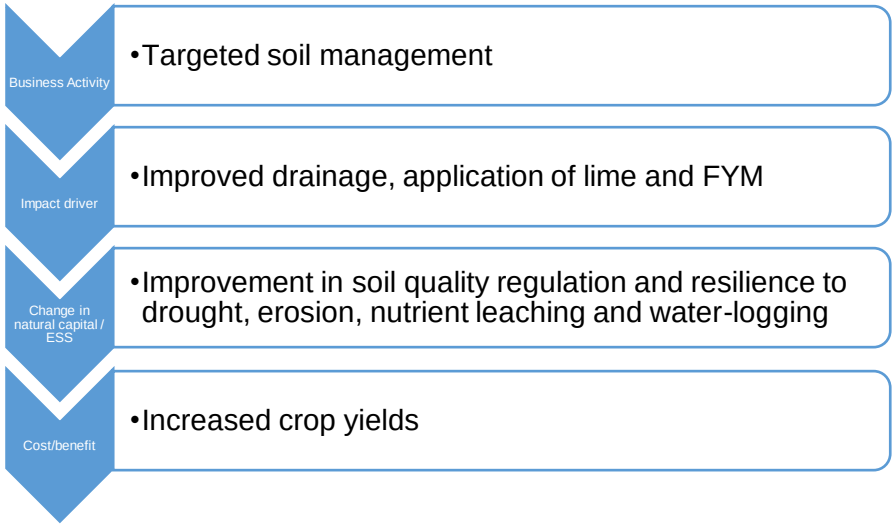
MEASURE AND VALUE STAGE: How?

Step 05: Measure impact drivers

Climate regulation; the main impact drivers for changes in greenhouse gas emissions (GHGs) are habitat cover and land use change, the number of livestock and the energy required for operating crop and livestock enterprises. For example, practices such as conservation tillage (e.g. no/min-till), retaining crop residues, including cover crops in crop rotations, and adding organic nutrient sources such as manure, all reduce carbon dioxide emissions and help to sequester atmospheric carbon in soil organic matter. No measures of GHGs are currently available for Den Farm, but it is anticipated that a carbon footprint analysis will be carried out in due course, as part of the QMS (Quality Meat Scotland) scheme.

Soil quality regulation; the main impact drivers here are changes in drainage and the application of lime and farm yard manure. Improving drainage reduces water-logging and restores soil microbe populations. Applying lime helps to reduce soil acidity, which improves microbial activity and the availability of nutrients. Applying farm yard manure adds humus and structure to the soil and encourages earth worms. All of these changes have the effect of improving soil quality, increasing soil fertility, and aiding water and nutrient retention.

The impact pathway showing the 'logic chain' from business activity to impacts on natural capital and the costs and benefits associated with these impacts is shown below.



Wild species diversity; the nature of crop and livestock production is not beneficial to wild species diversity (e.g. pollinators and birds), as these enterprises are based on growing a restricted number of cultivated species. However, soil rotation and adding organic matter does improve earthworms and micro-organisms. There was no data on biodiversity and soil biota available for Den Farm.

Step 06: Measure changes in the state of natural capital

Table A below sets out the asset register for this case study, detailing the interventions taken to improve soil quality on Den Farm and the resulting changes in the state of natural capital on-farm. There are also off-farm impacts to consider, such as the impact of sourcing lime and minerals from elsewhere, but these are outside the scope of this study. Adding lime to soil improves pH and uptake of other soil nutrients, such as phosphorus. Phosphorus is a finite (limited) resource. Resource efficiency is key: Richard used soil analysis and advice to understand the right amount of inputs required, reducing waste. Field margins on the farm prevent leaching of nutrients to water courses. Crop rotation, livestock manures and min-till farming, may help reduce the amount of fertilisers required in the future.

Table A: Case study asset register

		Start of tenancy 2016		Management interventions	Current status 2017	
	Natural capital asset	**Hectares**	**Data source**	**Activities undertaken**	**Hectares**	**Data source**
Extent	Cropland	121	Savills	Laid 42 ha to grass	86	Farm map
	Temporary pasture	5	Savills	Increased grassland to 42ha	42	Farm map
Condition	**Quality Indicators**	**Status / Score**	**Data source**	**Activities undertaken**	**Status / Score**	**Data source**
	Organic matter	completely lacking	Observation farmer	Added farm yard manure	Some organic matter in soil, but expected to be still low	Farmer
	Drainage	in state of disrepair due to deep ploughing by previous tenant	Observation farmer	Repaired most drainage	Majority of drainage repaired	Farmer
	Soil structure	high levels of compaction	Observation farmer	Cultivating practices; plough, press and one pass harrow/drill/roll	The soil is still quite compacted.	Farmer
	pH	low from 5.0 - 5.9	soil tests	Liming the soil to increase pH to improve uptake of nutrients and crop yield	pH increased, but still low. Can only be built up in stages	Farmer
	Extractable P	Lowerhalf of moderate	soil tests	Nutrients added according to advice based on soil analysis	Not known until future soil test	not available
	Extractable K	Upperhalf of moderate	soil tests			
	Extractable Mg	Low to moderate	soil tests			
	Trace elements	copper and zinc deficiencies	leaf analysis	Give nutrient bolus to cattle to improve cow and calve health		

Step 07: Value impacts

Soil improvement costs and crop yield increases are set out in Table B.

Table B: Costs and yield increases

T0 = start of tenancy 2016; T1 = 2017; T2 = 2022

Soil improvement cost	T0	T1	T2	Notes
- materials	£1,380	£4,054	£1,536	33% is cost of nutrients
- labour	£160	£942	£342	
- other costs	£0	£1,848	£856	
Total cost of soil improvement	**£1,540**	**£6,845**	**£2,734**	
Crop yield increase	**T0**	**T1**	**T2**	**Notes**
spring barley - t/ha	5.8	6.2	6.8	based on 63 ha
winter wheat - t/ha	8.4	8.9	9.4	based on 10 ha
spring barley - additional yield £		£4,032	£10,080	T2 compared to T0
winter wheat - additional yield £		£680	£1,350	
Total crop yield increase		**£4,712**	**£11,430**	

Costs to improve soil quality include bought-in lime (for 46ha in T1 and 32ha in T2) and fertilisers (yearly, for 128ha), adding farm yard manure (free, apart from application costs) and repairing drainage.

Crop yield gain:

- Reducing nutrient deficiencies makes plants stronger/healthier, more resistant to disease and pests, increasing yields.
- Spring barley is increasing from 5.8 t/ha in T0 to 6.8 t/ha by T2, with yields increasing by £4,032 in T1 and £10,080 by T2 (based on 63 ha and 2017 prices)
- Winter wheat is increasing from 8.4 t/ha in T1 to 9.4 t/ha by T2, with yields increasing by £680 in T1 and by £1,350 by T2 (based on 10ha and 2017 prices)
- After T1, the increase in crop yield starts paying back the costs of soil improvements.

A summary of the marginal costs and benefits is set in Table C. This represents an approximate benefit-cost ratio of 4.2:1 by 2022.

Table C: Marginal costs and benefits

Year	2016	2017	2022
Costs	£1,540	£6,845	£2,734
Benefits	-	£4,712	£11,430

In addition, there are animal health and welfare gains:

- Calves reared; 40 calves were reared from 40 suckler cows, higher than the industry average (Nix 2017: average 91 out of 100, equivalent to 36.4 calves reared)
- Reduction in vet & med costs: slight reduction expected.

APPLY STAGE: So what?

Step 08: Interpret and test results

Since Richard has taken over the tenancy of Den Farm, he has made a significant investment in soil quality (part of a five year plan). Harvest results for 2017 show higher yields than at the beginning of the tenancy. Further liming will be required to increase pH to the right level. Given the high cost of adding nutrients, there is a balance to be struck between increasing yields and adding costs.

Step 09: Take action

Adding farm yard manure will further improve soil organic matter and soil structure at little cost. Rotational crops may help keep up fertility of the land. Cover crops and min-till farming could also help improve the soil. In future, precision farming using GPS-technology may help pinpoint specific areas that need additional nutrients, enhancing resource efficiency of the farm.

Appendix 1: Glossary

Where available, definitions are taken directly from the Natural Capital Protocol[5].

Baseline	In the Protocol, the starting point or benchmark against which changes in natural capital attributed to your business' activities can be compared.
Biodiversity	The variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems (UN 1992).
Ecosystem services	The Millennium Ecosystem Assessment defines these as "benefits people obtain from ecosystems".
Natural capital	The stock of renewable and non-renewable natural resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people.
Natural capital dependency	A business reliance on or use of natural capital.
Natural capital impact	The negative or positive effect of business activity on natural capital.

[5] Natural Capital Coalition. 2016. "Natural Capital Protocol". (Online) Available at: www.naturalcapitalcoalition.org/protocol

Appendix 2: Ecosystem service descriptions

These are not intended to set definitive or exclusive interpretations of the listed ecosystem services, but can be used as an indication of the range of services to which this report refers, and the general meaning of those terms.

Air quality regulation	The regulation of air quality by ecosystems (e.g. the absorption of air pollutant particles by tree leaves)
Climate regulation	The capacity of ecosystems to influence the climate to improve local conditions (e.g. through a tree's shade) or mitigate global climate change (e.g. through the fixing of atmospheric carbon in woodlands)
Crops	The capacity of the ecosystem to support crop production
Cultural heritage	The value of cultural heritage arising from a community's historic relationship with its surrounding ecosystem
Disease & pest regulation	The capacity of ecosystems to regulate and control native or introduced pest and disease (e.g. slug predation by amphibians, or parasite exclusion through microclimatic conditions)
Education	The capacity of ecosystems to invoke interest and curiosity about the natural world
Fibre	The production of fibres and materials such as wood, skin, wax or flax for use as inputs for manufacturing or in their unprocessed forms
Flood regulation	The regulation, by upstream ecosystems, of water flows to prevent or mitigate flooding events downstream
Fuel	The provision of wood or other natural materials which are burnt or otherwise broken down to release energy, usually as heat.
Genetic materials	Genetic material (e.g. DNA), from all living organisms used, for example, in medicine, breeding programmes and research
Livestock	The capacity of the ecosystem to support livestock growth
Pollination	The service provided by wild pollinators in pollinating dependent crops and thereby enhancing yields
Recreation	The provision of views and experiences that promote and enhance recreation
Soil quality & erosion regulation	The capacity of ecosystems to stabilise, build and enhance soils
Timber	The provision of timber for use in construction and manufacturing
Water quality regulation	The regulation, through the filtering of sediment and the use of nutrients and pollutants, of ecosystems to improve water quality for human use
Water Supply	The provision of freshwater from ground or surface waters
Wild foods (fish)	The provision of wild freshwater and marine fish for food
Wild foods (game)	The provision of game animals for food
Wild foods (venison)	The provision of wild deer populations for food
Wild Species Diversity	The range of species which provide benefits to people through their aesthetic, natural history and existence. Biodiversity also contributes to the health and functions of ecosystems.

Appendix 3: Supplementary maps

See separate document