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Cranfield University

A valuation of the natural capital of the Cam and Ely-Ouse catchment

Final report prepared for WWF-UK

August 2017

Executive summary

The aim of the project is to provide a high-level assessment of the value of natural assets in the Cam and Ely-Ouse (CamEO) catchment.

The results of this project can help to inform CamEO stakeholders on key priorities for improving natural capital in the context of a catchment based approach and an evidence base on natural capital that can be further developed over time. It provides proof of method for the application of natural capital accounting in a catchment.

The estimated flow of ecosystem services are valued between £200 million to £320 million per year in the CamEO catchment. These services include: provisioning services (agriculture, timber and water abstraction: £64m - £179m), regulating services (carbon sequestration: £1.7m) and cultural services (recreational benefits: £135m).

The analysis of ecosystem service flows also indicates a range of stakeholders currently benefitting from the natural assets in CamEO including farmers, water companies, other business, households and wider society.

The results are based on a partial assessment with a range of important services requiring more detailed modelling, including flood risk mitigation and water purification services. There are also particular challenges for valuing biodiversity. The report provides illustrative evidence to highlight that people place significant value on biodiversity in the catchment.

Executive summary - 2

The Cam and Ely Ouse catchment includes important woodland, water resources and agricultural assets. Over 80% of the land is used by agriculture with 70% of this for cereal production.

The intensive agricultural usage of the land to produce cereal and other crops in this catchment provides key challenges for the soil and therefore the natural capital of the area. Soils provide valuable ecosystem services, including crop provisioning and water regulation but are subject to pressures and drivers that lead to soil degradation.

For this project, we are able to undertake innovative analysis using a soilscapes methodology developed by Cranfield University which is able to model soil degradation risks by different land uses and soil types and value the damage costs both on-farm and catchment wide on provisioning services, carbon, water quality and flood risk.

The analysis focuses on the impact of intensive agriculture in the catchment on compaction, erosion and soil carbon loss and estimates that in total, soil degradation costs about £39m a year with a range of stakeholders affected.

This indicative analysis demonstrates the potential scope for investments in natural capital that reduce soil degradation to deliver a range of benefits and can be a useful starting point for further work to identify value for money natural capital investments.

Natural capital in the Cam-EO catchment provides ecosystem services, which support economic growth and well-being

Plus support for flood management, biodiversity and water quality

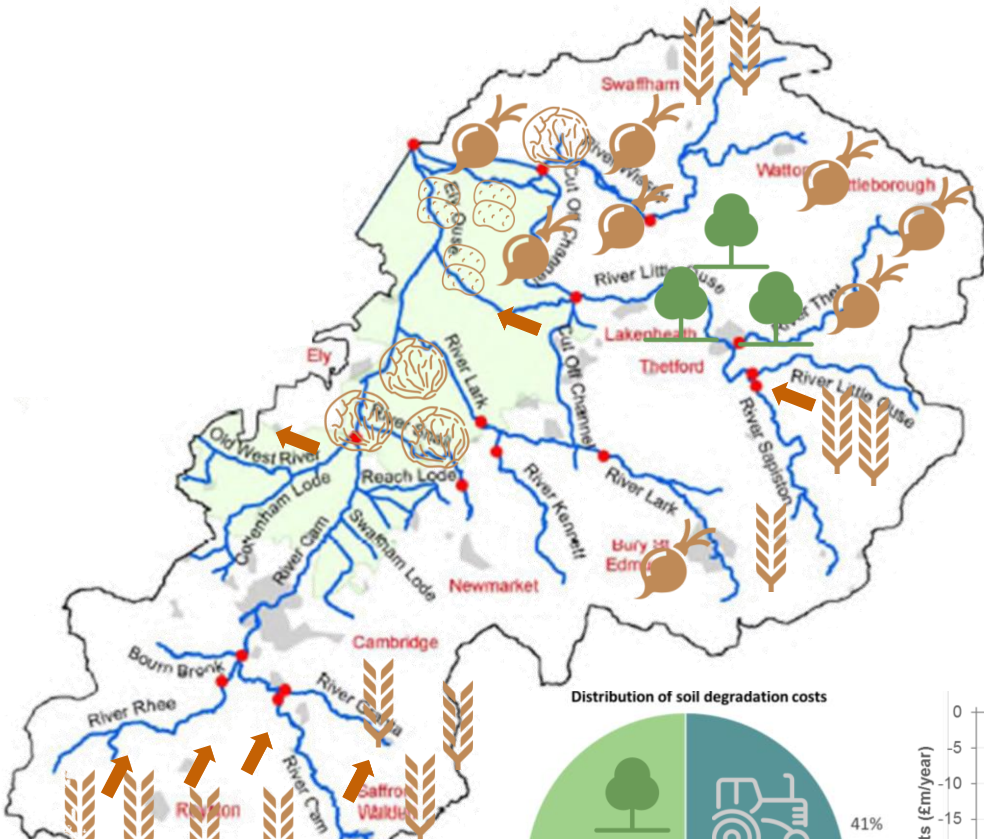
£1.7 million/year carbon sequestration services

£8 million/year in timber and £44 million in crops

£20-135 million/year water use provisioning

£135 million/year in recreation benefits

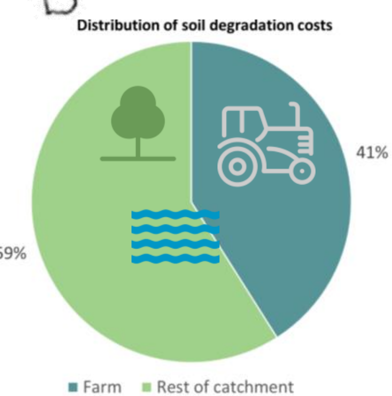
Natural capital assets provide ecosystem services valued at more than **£200 million/year**

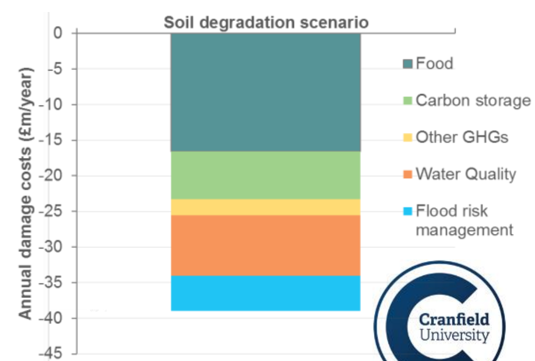


>Pressures<

Soil degradation related to intensive farming practices impacts on water quality, flood management and carbon storage across the catchment.

-£40 million/year





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Introduction to the project

Project aim

To develop a robust methodology to value the natural capital assets within the Cam and Ely Ouse (CamEO) catchment.

Desired outcomes

An evidence base that supports dialogue between stakeholders in the catchment.

Background

The Rivers Trust and WWF-UK are collaborating on a water stewardship project in the CamEO catchment focusing on water-sensitive farming.

Water resources in the CamEO are under increasing pressure from rising water demands for agriculture and public water supply, changing regulation and future climate uncertainty.

The catchment stands to benefit from a framework for long-term natural asset management.

Defra's forthcoming 25 year environment plan expected to recognise catchments as key building blocks for natural capital management, for which this work could act as a pilot.

The value of natural assets and analysis of the pressures on them can inform decisions

Drivers/pressures

Analysis using drivers, pressures, state, impact, responses (DPSIR) framework

Informs and provides context such as risks and degradation, and informs potential responses

Natural capital accounts

High level account of key natural assets in catchment

Priority ecosystem services and analysis of values associated with services

Responses

Can inform decisions over responses

Natural capital accounts can help:

- Assess how processes such as soil degradation affect service flows and loss of benefits;
- Scope potential improvements;
- Illuminate who benefits from improvements and who might pay for them;
- Monitor changes in the state of natural assets over time.

Natural capital accounting can inform…

Historical trends/future projections	*Trends over time in natural capital values*	Scenarios analysis	*Model a range of scenarios including change in land use, prices, climate, population*
Risk Register	*Prioritisation of risks to natural capital*	Sub-catchment natural capital accounts and analysis	*Apply valuation methodology on sub-catchment and farm/estate level*
Funding analysis	*Stakeholder analysis of maintenance of natural capital assets*	Asset-specific analysis	*Consider investment required to maintain/improve specific assets (e.g. aquifer)*
Prioritisation of interventions	*Cost-benefit analysis of specific interventions to maintain or improve natural capital*	Sensitivity analysis	*Model values over a range of parameters to produce robust results*
Tools for decision making under uncertainty	*Methods to value changes in natural capital when uncertainty around future changes and conditions exists*		

Contents

Accounts provide a systematic approach to reporting assets and services within a catchment

Natural capital accounts have both physical and monetary forms. The physical form records land uses and services. The physical accounting step allows stakeholders to agree on the assets, services and quantities of flows. The monetary forms can inform decisions on spending, rights and obligations.

In this report the asset typology is quite aggregated. Further disaggregation and analysis is possible, requiring data collection which is outside the scope of this phase of work.

Ecosystem services are defined within a standard typology of provisioning, regulating and cultural services.

The physical natural capital accounts provide an indication of the quantity and condition of the key habitats in CamEO

Table 1. **Physical asset account for natural capital in the CamEO catchment**

Natural capital quality indicators

Natural capital assets	**Area*** *ha*	**Provisioning output***	**Biodiversity (indicator)****	**Soil*** *(tonnes carbon stored)*	**Ecological condition**** *water quality*	**Access***** *e.g. access paths*
Woodland – Broad leaf	20,670	370,000 m^3/pa wood harvested	203 SSSIs in catchment	91		1.5 million visitors to Thetford forest/year
Woodland - Coniferous	16,500			82		
Enclosed Farmland – Arable and horticulture	238,200	Crops		106		
Enclosed Farmland – Improved grassland	58,840	Livestock		114		
Semi-natural grasslands	14,920	Livestock		306		
Water – Fen marsh and swamp	220		Fens included in priority habitat list	224		
Water – Freshwater	1,370	130 million m^3/pa water abstracted		133	18 per cent 'Good' under WFD	Recreational use includes angling
Mountains, moorland and heath	770			81		

*Sources: *Cranfield University, **Environment Agency and ***Forestry Commission*

Note: Land classified for 'urban' use is not included in above accounting. CamEO catchment includes 17,650 ha of urban land.

Natural capital accounting values the annual flow of ecosystem services in the catchment

Ecosystem services valued in this study provide more than £200 million in benefits each year

Table 2. **Estimated economic service flows for natural capital accounts, £m per year**

<table>
<tr><th></th><th colspan="3">Provisioning services</th><th colspan="3">Regulating services</th><th colspan="2">Cultural services</th><th></th></tr>
<tr><th></th><th>Food</th><th>Water Abstraction</th><th>Timber</th><th>Carbon sequestration</th><th>Water quality (farmed land)</th><th>Flood risk management</th><th>Recreation</th><th>Biodiversity</th><th>Total</th></tr>
<tr><td>Woodland</td><td></td><td rowspan="4"></td><td>8</td><td>1.5</td><td colspan="2" rowspan="6">Not available</td><td rowspan="6">135</td><td rowspan="6">Not available</td><td>10</td></tr>
<tr><td>Enclosed Farmland – Arable and horticulture</td><td>44</td><td rowspan="5"></td><td>0.1</td><td>44</td></tr>
<tr><td>Grasslands</td><td>[-8]</td><td>0.1</td><td>[-8]</td></tr>
<tr><td>Water – Fen marsh and swamp</td><td rowspan="3"></td><td>0</td><td>-</td></tr>
<tr><td>Water – Freshwater</td><td>20 to 135</td><td>n/a</td><td>20 to 135</td></tr>
<tr><td>Mountains, moorland and heath</td><td></td><td>0</td><td>1</td></tr>
<tr><td>Recreational benefits</td><td colspan="8"></td><td>135</td></tr>
<tr><td>Total</td><td>36</td><td>20 to 135</td><td>8</td><td>1.7</td><td>-</td><td>-</td><td>135</td><td>-</td><td>201 to 317</td></tr>
</table>

Notes: Grasslands cover improved grasslands and semi-natural grasslands. Recreational benefits are not currently disaggregated by habitat type in this analysis..

Pressures and risks to natural capital in the CamEO catchment

This project provides a high-level assessment of the drivers and pressures in the CamEO catchment impacting on natural capital.

An analysis of drivers and pressures on natural capital provides important context to the natural capital accounts as it provides insight on future trends in natural capital, ecosystem service flows and benefits delivered to the economy and society.

Natural capital assets can be affected by changes in the economic, political and environment inputs to the systems they support. The principal pressures are climate change, social, especially future population growth and market pressures to increase food production.[1]

The analysis uses an innovative 'soilscapes' method previously developed by Cranfield University and applied to the catchment context to consider the impacts on natural capital of various soil degradation risks.

The analysis includes estimates of the costs of soil degradation in terms of both on-farm costs and external costs and linked to a range of ecosystem services in the catchment. These impacts reduce the potential benefits by around £39m in the CamEO catchment.

1 Source: Environment Agency, The Cam and Ely Ouse Management Catchment, 2014

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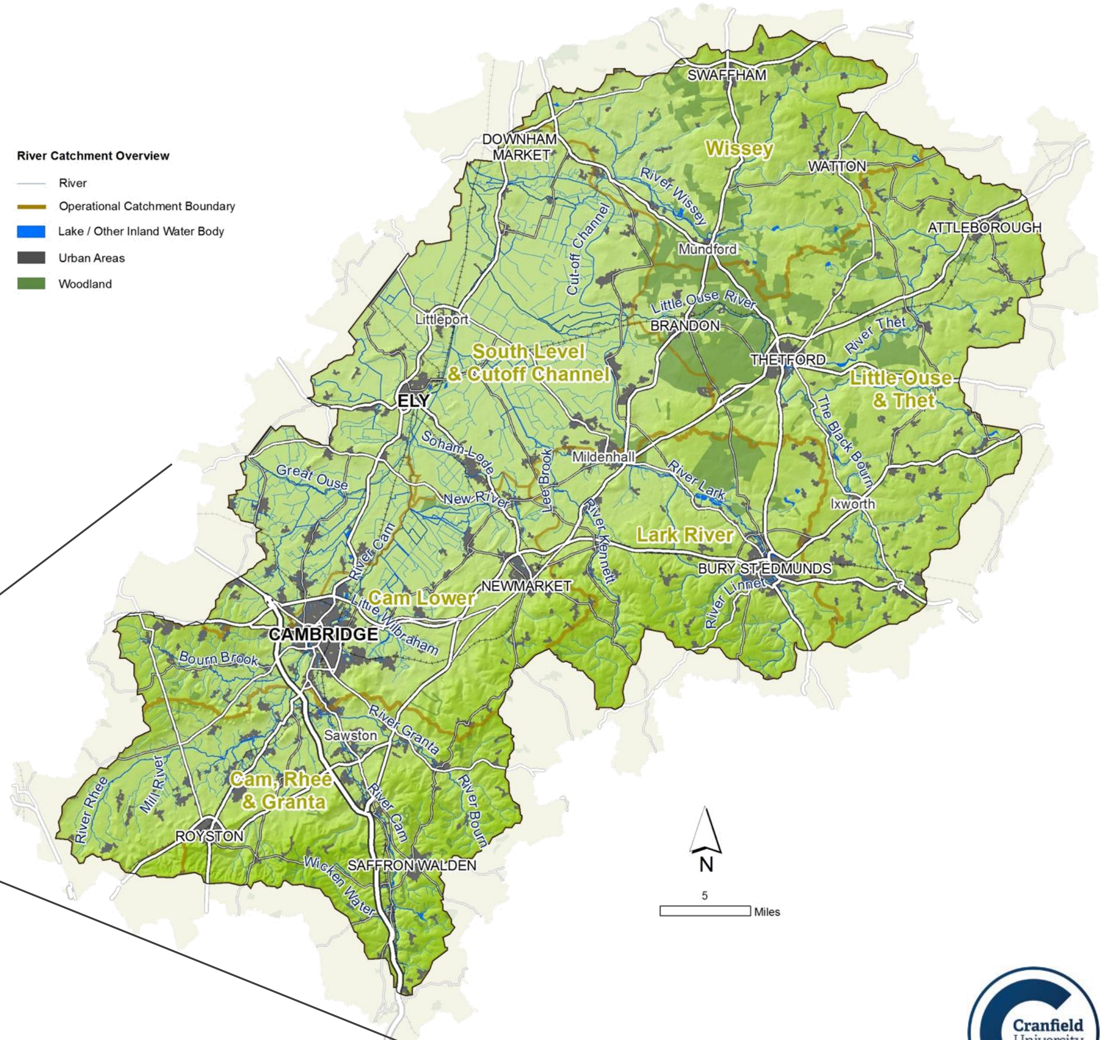
The CamEO catchment: a brief description

This section summarises the geography and land-use of the CamEO catchment derived from published statistics and use of geospatial datasets.



Source: Cranfield University (2015), The Rivers Trust

The Cam and Ely Ouse catchment includes important woodland, water resources and agricultural assets

The CamEO catchment covers 3,700 km^2 (370,000 ha) and includes the following features:

- Urban areas: Cambridge (pop. 124,000), Bury St Edmonds (pop. 40,000), Ely (20,000), Newmarket (pop. 20,000), Royston (pop. 16,000), Saffron Walden (pop. 14,000), and Swaffham (pop. 7,000);
- National forest resources and protected areas: Thetford Forest, 4 Special Areas of Conservation, 1 Special Protection Area, 203 Sites of Special Scientific Interest;
- Rivers: the River Great Ouse and four main tributaries (Cam, Lark, Little Ouse and Wissey) and two important aquifers providing groundwater resources;
- Fenland marsh and chalkland habitat.

The region produces a significant share of the UK's cereals, vegetables, potatoes and sugar beet crop.

Over 80 % of land in catchment is used for farming

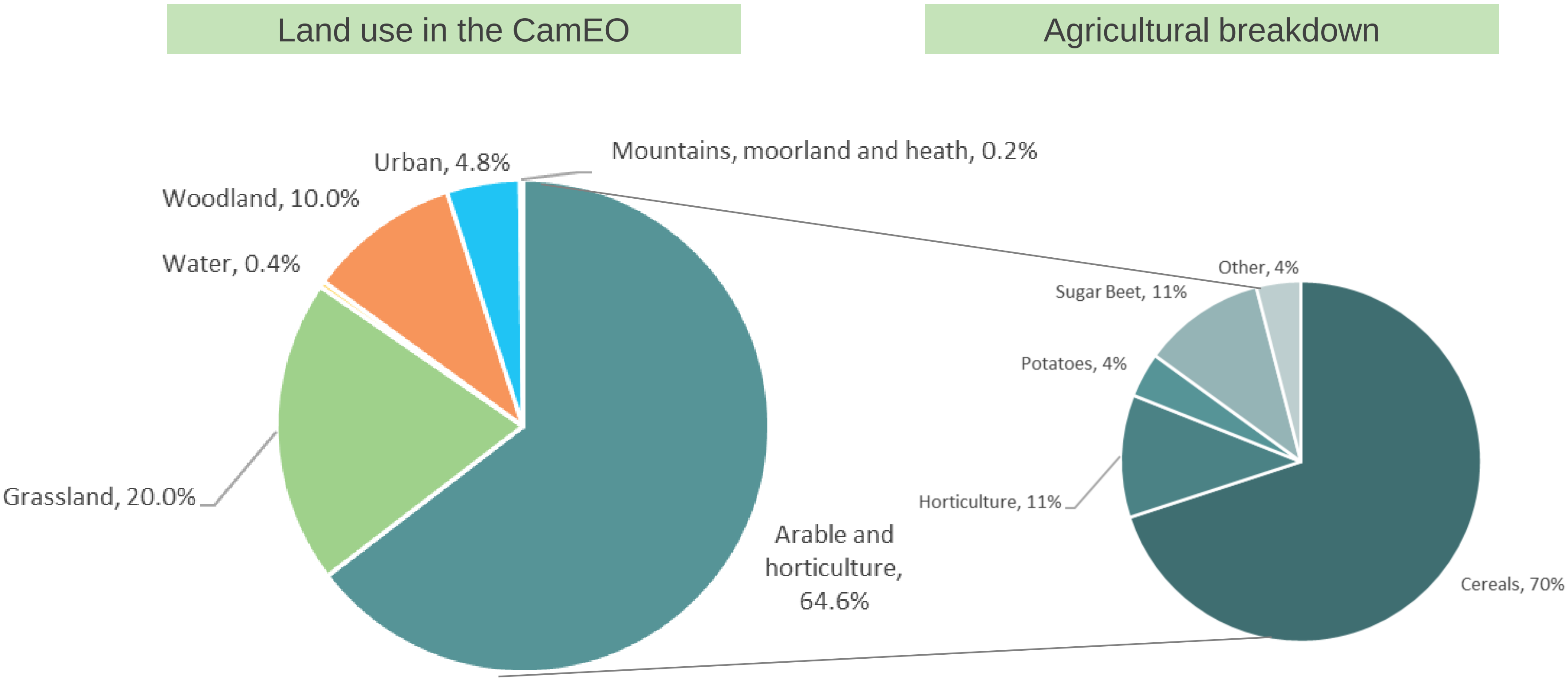
Table 3. **Classification of major land cover types in the CamEO catchment**

Land cover class		Area (ha)	Share of total
Woodland	Broad leaved, mixed and yew woodland	20,368	5.5%
	Coniferous woodland	16,500	4.5%
Enclosed farmland	Arable and horticulture	238,205	64.6%
	Improved grassland	58,840	16.0%
Semi-natural grassland	Rough low-productivity grassland	12,210	3.3%
	Calcareous grassland	6	0.0%
	Neutral grassland	2,705	0.7%
Open water, wetlands, floodplains	Fen marsh and swamp	222	0.1%
	Freshwater	1,370	0.4%
Mountains, moorlands, heath	Dwarf shrub heath	396	0.1%
	Inland rock	373	0.1%
Coastal margins	Supra-littoral sediment	5	0.0%
Urban	Built up areas and gardens	17,652	4.8%
All land cover	**Total**	**368,852**	**100.0%**

Over 80 % of land in the catchment is used for farming

Source: Vivid Economics, Cranfield University based on data from CEH Land Cover Map 2007 Dataset

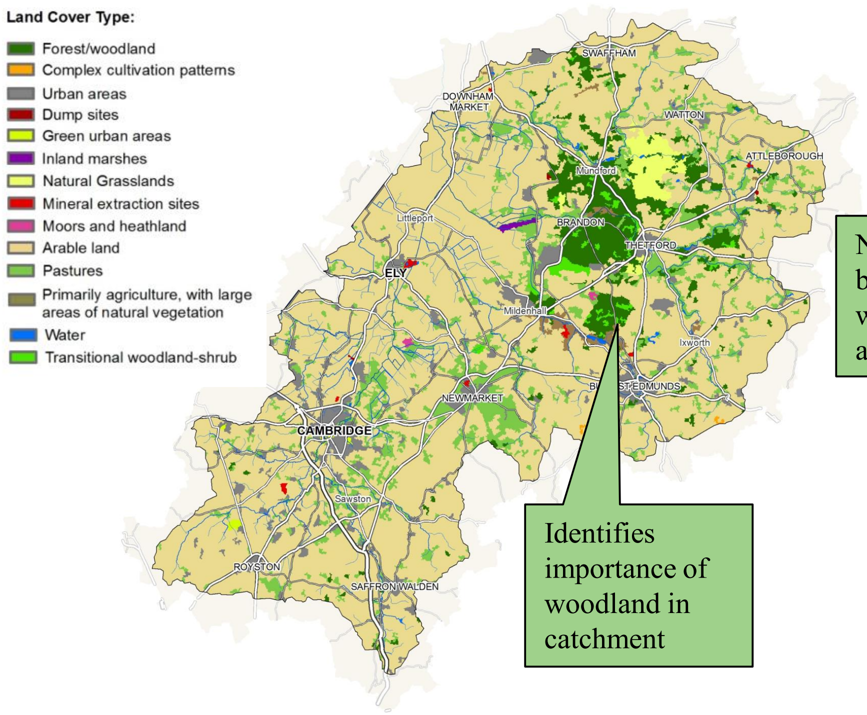
Cereal farming is the predominant agricultural activity in the region, followed by livestock grazing



Source: Vivid Economics based on data from CEH Land Cover Map 2007 Dataset

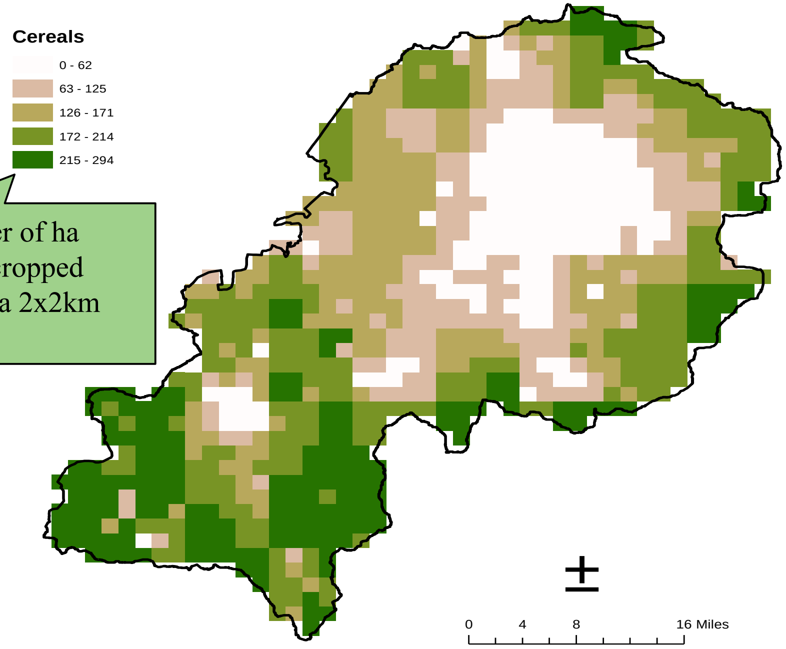
The top of the catchment contains most of the woodland, while the lower catchment is devoted to cereals

Land cover type in CamEO



Identifies importance of woodland in catchment

Cereal farming in CamEO



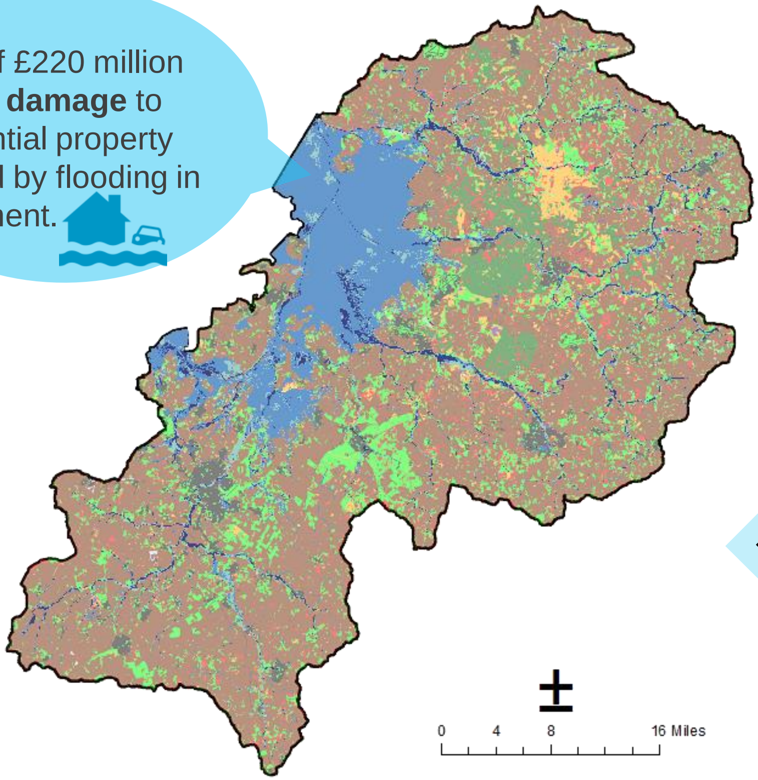
Number of ha being cropped within a 2x2km area.

Source: The Rivers Trust, Cranfield University based on data from EDINA Agcensus Service for England (2010)

Rivers in the catchment flow to the north west where fenland areas are at risk of flooding

Flood risk in CamEO

Risk of £220 million annual **damage** to residential property caused by flooding in catchment.



High flood risk (*)

Rivers in CamEO

Source: Cranfield University based on data from EDINA Environment Digimap Service (CEH-LCM2007), Environment Agency
* Current risk, accounting for existing infrastructure for flood defence. See later section for flood risk mitigation services.

Most of the catchment sits over the CamEO Chalk aquifer

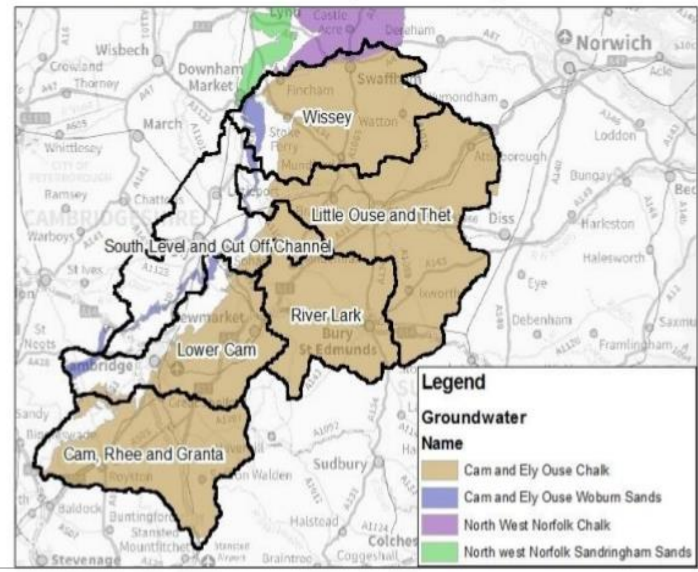
Table 4. **Water bodies in CamEO catchment**

	river water bodies	lakes	groundwater
Number of water bodies in catchment	69	5	2
Cam, Rhee and Grant	18	0	2
Lark	12	0	1
Little Ouse	18	1	1
Low Cam	10	1	1
South level	3	1	2
Wissey	8	2	1

There are two important aquifers providing groundwater resources in CamEO:

- The largest is the Chalk, under the eastern and central part of the area. It is primarily exploited for public water supply and spray irrigation and is important for providing base flows.
- The other principal aquifer, Lower Greensand (Woburn Sands), is significantly smaller than the Chalk aquifer but remains locally important for the provision of drinking water.
- The state of the aquifers is described as poor by the Environment Agency.

Groundwater in the Cam and Ely Ouse Management Catchment



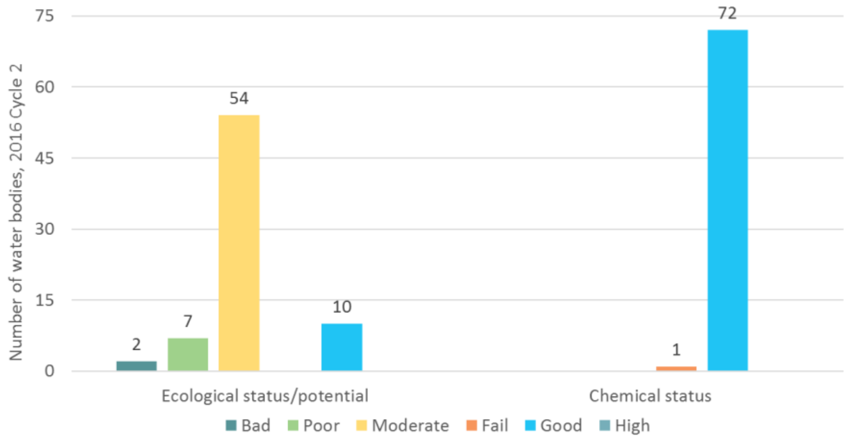
Source: Environment Agency, 2014: https://www.slideshare.net/CLAEast/farm-business-update-2014-thetford-ea-and-water-framework-directive

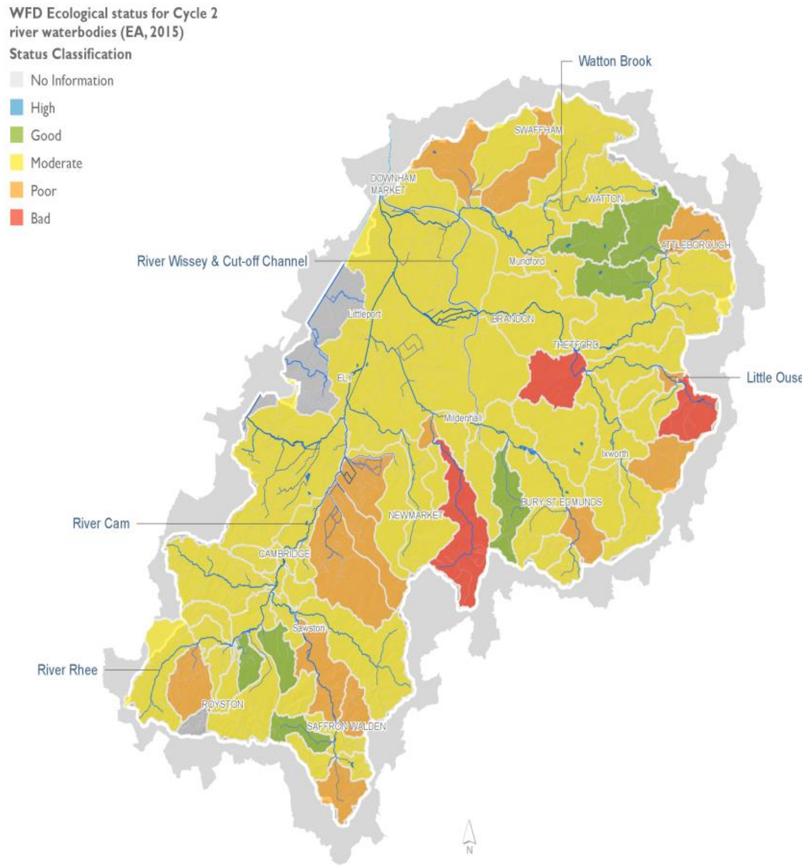
The proportion of water bodies considered in ‘good ecological status’ in CamEO catchment has been declining

Approximately 14% of water bodies in the catchment are currently classified under good ecological status, down from 19% in 2009 (*).

Key priority river basin management issues to tackle in this catchment include diffuse pollution in rural areas, biological impacts of low flow rates and over-abstraction and nutrient loading.

The whole Cam and Ely Ouse catchment is designated a Nitrate Vulnerable Zone (2013) for surface water and, in part, for groundwater under the EC Nitrates Directive.





Source: The Rivers Trust, Environment Agency

(*) Changes in status can be owing to new and improved knowledge of water bodies and data collection factors.

Biodiversity in the catchment includes species in designated Sites of Special Scientific Interest (SSSIs)

203 Sites of Special Scientific Interest (SSSI) identified within the Cam and Ely Ouse spread over a total 43,189 ha, of which 18,249 ha are in favourable condition.

Protected areas provide one picture of biodiversity in the catchment.

Natural England has set a goal of 50 % SSSIs with a 'Favourable' rating and 45 % 'Unfavourable recovering' rating by 2020. CamEO would have to move 3,400 ha of its protected areas to 'favourable' to meet this goal.

Other biodiversity assets in the catchment are reflected in the habitats covered under the UK Biodiversity Action Plan, shown in the map appendix to this report.

Table 5. **Sites of special scientific interest in CamEO catchment, by condition**

Condition	Number of sites	Area (ha)	Share of total area
Destroyed	2	18	0.04%
Part destroyed	2	7	0.02%
Unfavourable declining	17	320	0.74%
Unfavourable no change	17	570	1.30%
Unfavourable recovering	77	24,000	56.00%
Favourable	88	18,000	42.00%
Total	**200**	**43,000**	**100.00%**

Source: Cranfield University based on data from Natural England MAGIC mapping system

Contents

Ecosystem service flows in CamEO

This section describes the priority ecosystem services in the CamEO.

The ecosystem services underpin economic activity and wider societal welfare. They can be quantified, and valued where feasible and appropriate.

They include:

- Provisioning services: agricultural services (crop production), water abstraction (value of water and quantity of drinking water), woodland (timber);
- Regulating services: carbon sequestration in plants and soil, water purification, flood risk management;
- Cultural services: recreation and biodiversity (non use values).

Logic chains are presented for each service which provide a summary mapping from the ecosystem asset to the delivery of the service and to the value of the service to beneficiaries. Where appropriate, the slides include valuation tables.

Further information on the methodology for calculation of service value flows can be found in Appendix A.

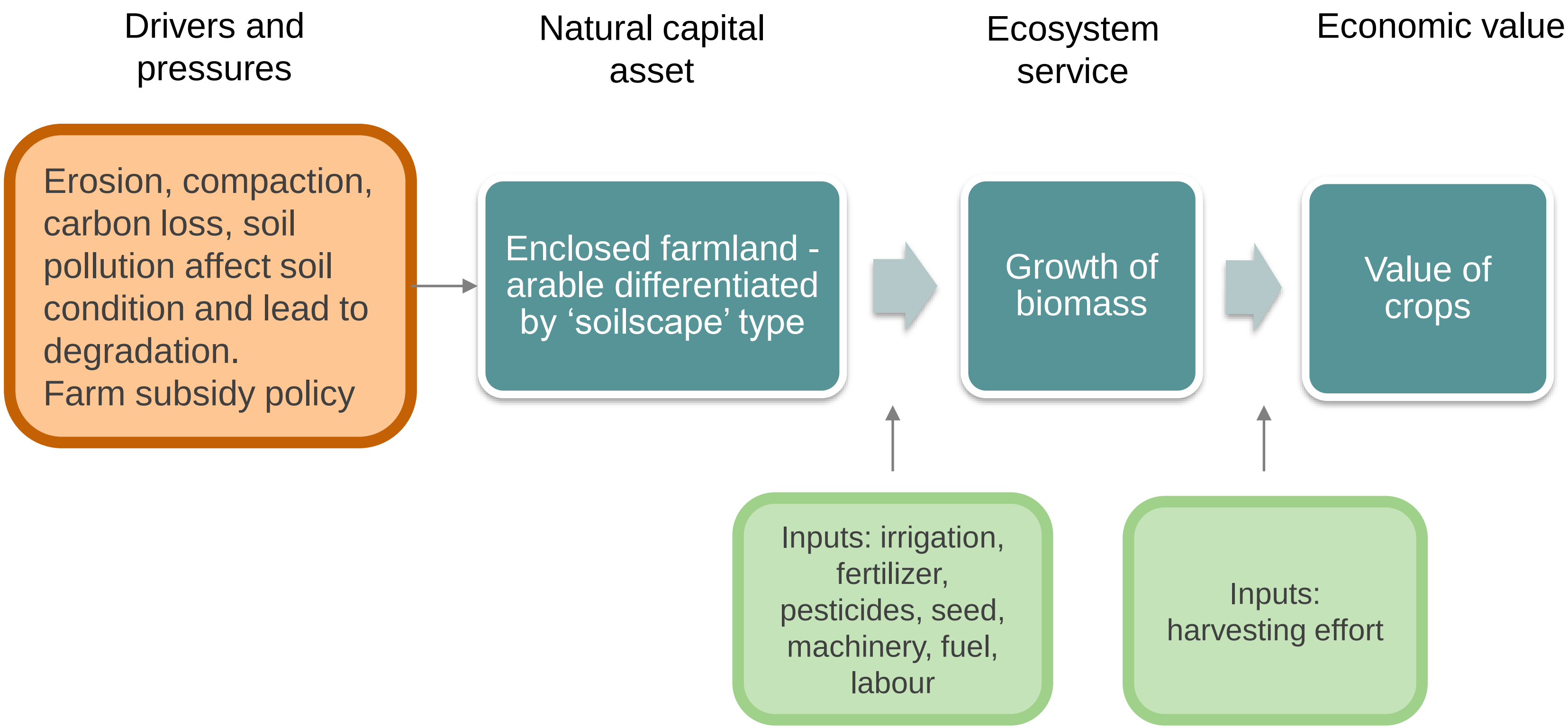
Ecosystem services support economic activity and societal well being in the catchment

Ecosystem services can be quantified and valued where appropriate in monetary terms to provide an indicative picture of the economic welfare they bring to users in the area. This approach can also be used to highlight the costs to service flows arising from degradation scenarios (e.g. from soil degradation).

Table 6. **Ecosystem services and costs valued in this study**

	Provisioning services	Regulating services	Cultural services
Ecosystem Services	– Farmland provides crops – Grassland provides feed for livestock – Woodland provides timber – Surface water provides water for abstracting	– Natural assets support water quality – Soil and vegetation provide flood risk management services – Vegetation sequesters carbon from the atmosphere, while soil stores carbon matter	– Woodlands, surface water and open spaces provide recreational benefits to users – Natural habitats support birds and other species that are valued by households
Costs (Soil Degradation scenario)	– Degraded soil reduces yields on farmed lands – Abstraction values for public water supply fall with higher treatment costs – Fertilizer costs increase with higher run-off rates	– Water treatment costs increase with nutrient and soil run off – Damage costs from reduced carbon sequestration – Damage costs from greenhouse gases resulting from fertilizer runoff – Costs of increased flood risks from soil compaction	

Agricultural provisioning services are particularly important in the CamEO catchment



Cropped land produces agricultural provisioning services valued at £44 million per annum

To determine the value of crops derived from natural capital assets **net farm income** is reported net of income support, labour, rent and interests and the costs of other inputs (fertiliser, seed, depreciation of farm machinery).

Grassland currently produces a negative net resource rent attributable to land once similar adjustments are made, reflecting dependency on income support and relatively high levels of unpaid family labour.

Table 7. **Value of crop provision attributable to natural capital (net of inputs)**

Land cover type	Area (ha)	Share	Net farm Income (£/ha)	Value (£ million/year)
Arable and horticulture	240,000	100%		44
o/w Cereals	*170,000*	*70%*	*190*	*31*
o/w Horticulture	*26,000*	*11%*	*470*	*12*
o/w General cropping	*45,000*	*19%*	*220*	*10*
Improved Grassland	74,000	100%	(-110)	(-8)

Note: There is a debate on use of resource rent approaches that derive negative values for the provisioning service – see Defra Principles of Natural Capital Accounting (2017), page 34.
Source: Cranfield University, data from Farm Business Survey (2016) for the East of England broadly equivalent to East Anglia

Water provisioning services: value of water abstraction

Public water supply and agriculture are most significant abstractors in the catchment

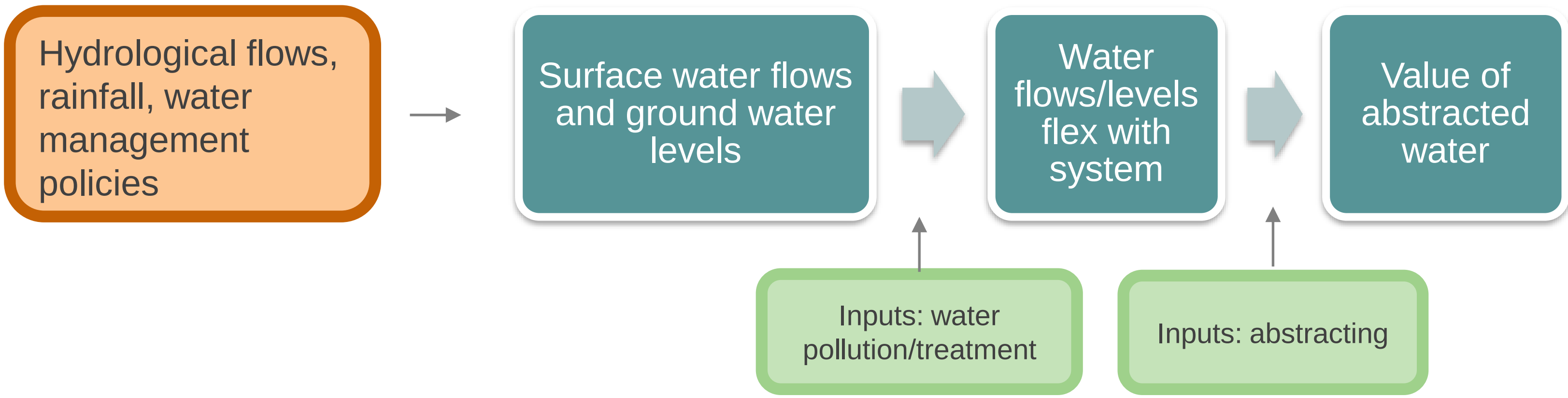


Table 8. **Value of water abstraction from ground and surface water supply in CamEO, 2015**

Sector	Estimated volume of water abstracted (m^3)	Unit value of abstraction (£/m^3)	Total value of abstraction (£m/year)
Agriculture	28,000,000	1.25	35.5[2]
Amenity[1]	2,600	0.15	0.0
Environmental[2]	24,000,000	0.30	7.2
Industrial, Commercial, public services	3,800,000	0.1-0.5	0.2-1.8
Production of Energy	80,000	0.1-1.0	0-0.1
Public Water Supply	81,000,000	0.15 – 1.5	12 to 124
Total	**130,000,000**	**-**	**55 to 170**

Source: Cranfield University, Vivid Economics calculations using unit values based on resource rents and UK National Ecosystem Assessment abstraction values. See Appendix 1 methodology for more details.
1 Amenity use includes water used for parks, golf courses, swimming pools, etc. Water abstracted for agriculture is reflected in crop provisioning values; 2 Environmental includes use in relation to river/wetland support, transfer between sources and pollution remediation.

Most water abstracted from groundwater and surface water in CamEO is used in the public drinking water supply

Based on published EA data, c. 130 Mm^3 abstracted in catchment in 2015

Table 9. **Water abstracted and licensed for abstraction in the CamEO catchment, 2015**

Sector	Volume licensed (m^3)	% of total	proportion abstracted
Agriculture	**55,656,300**	**9.6%**	**51.0%**
Surface Water	35,585,750	6.1%	46.0%
Groundwater	20,070,549	3.5%	59.0%
Amenity	**36,800**	**0.0%**	**7.0%**
Groundwater	36,800	0.0%	7.0%
Environmental	**342,441,238**	**59.1%**	**7.0%**
Surface Water	317,312,592	54.8%	5.0%
Groundwater	25,128,646	4.3%	24.0%
Industrial, Commercial, public	**10,557,719**	**1.8%**	**36.0%**
Surface Water	697,031	0.1%	60.0%
Groundwater	9,860,688	1.7%	35.0%
Production of Energy	**40,187,376**	**6.9%**	**0.2%**
Surface Water	39,893,040	6.9%	0.0%
Groundwater	294,336	0.1%	32.0%
Public Water Supply	**130,116,055**	**22.5%**	**62.0%**
Surface Water	6,570,000	1.1%	53.0%
Groundwater	123,546,055	21.3%	62.0%
Total	**578,995,488**	**100.0%**	**23.0%**

Source: Cranfield University based on Environment Agency National Abstraction Licensing Database (NALD)

Woodlands in CamEO produce forest goods valued at £8 million per annum

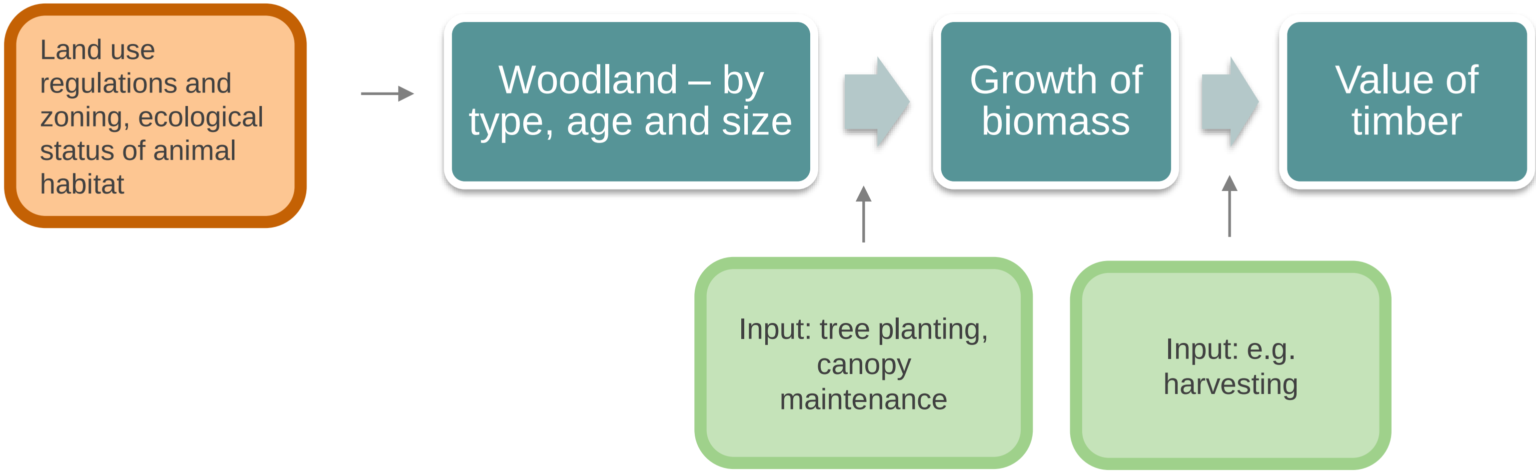


Table 10. **Value of timber provision from woodlands in CamEO**

Woodland Type	Catchment Area (ha)	Prices (£/m³)	Average output (m³/ha/yr)	Value (£ million/year)
Broad leaved	20,400	28	6	3
Coniferous	16,500	20	15	5

Source: Vivid Economics modelling, based on data from The John Nix Farm Management Pocketbook (2016)
Note: Average timber price assumed to reflect resource rent of timber, given low marginal costs after planting

Carbon sequestration contributes to an equitable climate

Values shown for baseline flows, which could be reduced by e.g. soil degradation

Land use changes, biomass stock; climate change affecting vegetative growth → Biomass including vegetation and woodlands → Carbon sequestered in biomass → Value of carbon kept out of atmosphere

Input: tree planting, canopy maintenance

Table 11. **Value of carbon sequestered in CamEO**

Land cover type	Catchment area (ha)	Share of catchment area	Carbon sequestered (tC/ha/year)	Total Value (2017 £ thousands)	Share of total
Woodland - Broad leaf	20,368	6%	1.36	482	29%
Woodland – Coniferous	16,500	5%	3.45	994	60%
Arable & horticulture	238,205	65%	0.03	121	7%
Improved grassland	58, 840	16%	0.029	30	1.8%
Semi-natural grassland	14, 921	4%	0.108	28	1.4%
Other	2,366	1%	0.98	2	<1%
Urban	17,652	5%	0.00	-	<1%
Total	**368, 852**			**1,656**	

Woodland areas provide £1.5 million in annual carbon services, 90% of the total value.

Farmland accounts for high share of land use but low share of carbon storage.

Source: Vivid Economics calculations. Sequestration rates from Defra report on developing ecosystem accounts (2015), cost of carbon (2017 BEIS)

Natural capital provides water purification services that can help to reduce water treatment costs

Key drivers & pressures including pollution from wastewater & rural areas → Natural assets including wetlands, woodlands → Water purification (reduced diffuse pollution, reduced sediment load) → Improvements in surface water and groundwater quality: biodiversity, recreation and avoided water treatment costs

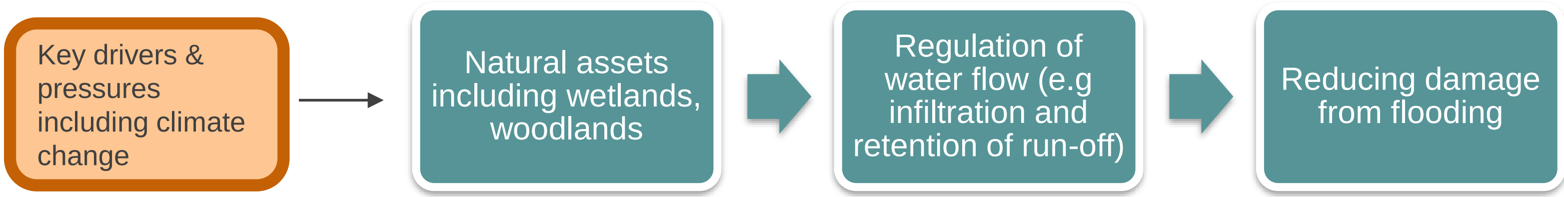
Natural assets intercept pollutants, remove sediments and prevent both from reaching watercourses. The value of theses services can be estimated through use of:

- Avoided water treatment costs: A ‘replacement cost’ method to estimate the cost of maintaining the quality of water supplied in the absence of natural asset’s role in pollution removal;
- Change in quality of water environment: A stated preference method using willingness to pay to improve the water quality of a river e.g. EA’s NWEB (national water environment benefit) values for Cam-EO;
- Value of abstracted water: A market price method using the fact that poor water quality will require higher treatment costs, lowering the value of abstracted water.

Valuation of this service requires detailed catchment level modelling, which is beyond the scope of this project.

Natural capital provides flood, storm and drought protection services by regulating water flows throughout the catchment

Residential property value 'at risk' in CamEO is estimated to be as high as £220 million



Natural assets can help in the regulation of water flow through flood storage and the reduction of volume and speed of peak flows.

Best practice for valuing the avoided damage costs of flood risk events including to properties and agricultural land require detailed catchment level modelling, which is beyond the scope of this project.

Approximately 16% of the CamEO catchment area is under flood risk. Most land at risk is agricultural. The urban area under flood risk (673 ha) represents a significant property value at risk. The value shown in Table 12 is not an ecosystem service flow, but an indicative assessment of expected annual residential damage costs in the catchment. It is based on a weighted average damage value for residential properties recommended by MCM.

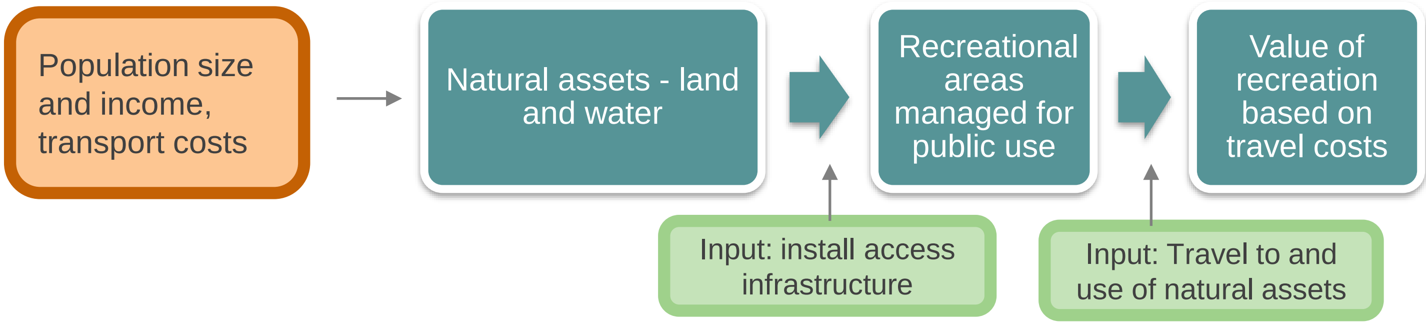
Table 12. **Indicative expected annual damage costs of residential properties in CamEO at risk of flooding**

	(£/property)	Value at risk (£ million)
Baseline flood risk	4,728	220

Soil degradation impacts on flood risk and can also provide an important indicator of the scope for benefits improvement which can be linked to possible catchment measures. We explore this further for the CamEO catchment in a later section of this report.

Source: Multi-coloured Manual (MCM), Weighted annual average damage calculations with no protection (2013 prices), Table 4.32
Note: Baseline risk calculation is estimated by applying the percentage of land area in the catchment at risk of flooding by the number of houses in local authorities covered by the catchment

Annual value of recreation benefits associated with visits to greenspace in CamEO is estimated to exceed £135 million



These values reflect the economic welfare enjoyed by individuals as a result of access to greenspace.

These estimated recreational values have been derived from ORVal and are based on what we might expect for a typical greenspace with the given features in CamEO accounting for the availability of other greenspace and the characteristics of the local population. The methodology for calculating recreational values is discussed in Appendix 1.

The recreational values reported here will not take account of aspects such as uniqueness of sites and particular types of recreational activities such as angling. It is based on day visits and so excludes overnight stays. The value to the tourism sector (e.g. associated with Cambridge punting) is not included so this should also be considered as additional.

Table 13 **Estimated annual value of recreation in CamEO of greenspace visits**

	Number of visits/year	Total value (£m/yr)
Total value of recreation	35 million	135

Source: Cranfield University using ORVal (2016), Outdoor recreation valuation tool. ORVal reports values and visit estimates for greenspaces that are derived from a sophisticated model of recreational demand in England based on data from MENE (Monitor of Engagement with Natural Environment).

Biodiversity is an important ecological asset, but presents challenges for valuation

Biodiversity values are not included in the overall service accounts in this study

The current state of practice is to make biodiversity visible in ecosystem service accounts through both the physical and monetary accounts if possible.

<u>Physical accounts:</u>

Recognise biodiversity as the asset which generates the benefits and use the assets accounts to report on physical biodiversity stock and condition indicators.

<u>Monetary accounts:</u>

Recognise that much of the value of biodiversity will be reflected through ecosystem service values since biodiversity underpins delivery of many services.

Non-use values for biodiversity (the value people place on wildlife for its own sake) can be added while recognising the difficulties in robustly valuing non-use and are only indicative of the values people hold.

Illustrative biodiversity values for catchment

Caution is needed in use of these values but illustrate high value people place on biodiversity

Table 14. **Examples of non-use biodiversity related values for SSSIs habitats across UK**

SSSI habitat	Stated preference value (£ / Ha/ yr)
Sand dunes and shingle	1,377
Heathland	1,141
Intertidal mudflats and saltmarsh	1,035
Bogs	1007
Broadleaved, mixed and yew woodland	1002
Lowland calcareous grassland	914
Rivers and streams	903
Fen, marsh and swamp	861
Acid Grassland	682
Canals	649
Neutral Grassland	642
Standing waters	622
Coastal and flood plain grazing marsh	450
Maritime cliffs	344
Purple moor-grass and rush pastures	312
Coniferous woodland	237
Inland rock	200

Source: GHK study for Defra (2011) – National figures, not catchment specific

Table 15. **EA NWEB values for CamEO catchment (£ per km improved)**

EA National water environment benefit (NWEBs) survey annual per km values, £000s, 2012 prices for rivers			
	Bad to Poor	Poor to Medium	Moderate to Good
Cam-EO NWEB values (central values)	15.9	18.2	21

Source: Environment Agency, updated values 2013

203 Sites of Special Scientific Interest (SSSI) identified within the Cam and Ely Ouse spread over a total 43,189 ha, of which 18, 249 ha are in favourable condition. **Valued at average of £707/ha/per year; this is equivalent to £13m per annum.**

This figure will include some overlap with other service values so needs to be treated with caution although the study indicated that the majority of respondents attributed their valuation to biodiversity.

The NWEBS provided values for recreation, amenity and non-use benefits from improving the water environment. The values presented in Table 14 are specific to the CamEO catchment and provide an illustration of the value per km of river improved including non-use biodiversity related values.

Monetary valuation of ecosystem services by end beneficiaries

Partial assessment highlights value of natural assets associated with a range of beneficiaries

Table 16. **Monetised benefits for baseline**

		Annual ecosystem service values - total and by end beneficiary				
		Total	Farmers	Water company	Household/ Society	Other business
Natural asset	Annual value of services, £m					
Food	Crop provisioning	**44.0**	44.0			
	Livestock (grass provision)	**-8.0**	-8.0			
Raw materials	Timber	**8.4**				8.4
Water provisioning	Water abstraction	**20 to 135**	36.0*	12 to 124	7.2 **	0.2 to 1.9
Equitable climate	Carbon stored	**1.7**			1.7	
Biodiversity	Flora and fauna	**13.0†**			13.0†	
Hazard protection	Avoided flood damage	**-**				
Cultural value	Recreation	**135.0**			135.0	

Note: Benefits will represent a partial assessment of services only.
** Presented in table but not included in total as implicitly included in crop provisioning services.*
*** Reflects value of water in use for environment. † Estimate provided for illustrative purposes only of the importance people place on existence value of biodiversity but is not included in the total.*

Contents

Drivers, pressures and risks – overview

An analysis of drivers and pressures on natural capital provides important context to the natural capital accounts as it gives insight on future trends in natural capital, ecosystem service flows and benefits delivered to the economy and society.

This project provides a high-level assessment of the key drivers and pressures in the CamEO catchment impacting on natural capital.

The section looks at one particular set of natural capital risks relating to soil degradation to provide a deep-dive on how we can integrate this analysis with natural capital accounting.

The analysis uses an innovative ‘soilscapes’ method previously developed by Cranfield University and applied to the catchment context to consider the impacts on natural capital of various soil degradation risks. The analysis includes estimates of the costs of soil degradation in terms of both on-farm costs and external costs and links to a range of ecosystem services in the catchment.

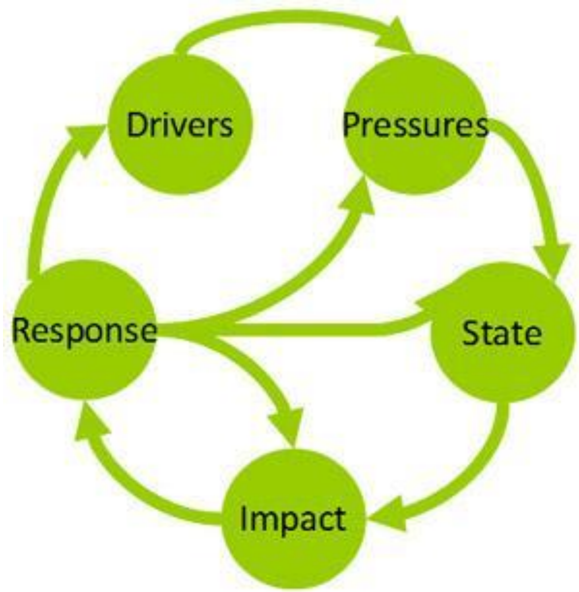
The analysis can identify key stakeholders who both contribute to the pressures as well as those who may bear the resulting costs. This analysis can therefore inform potential responses and help to identify stakeholders with an interest in reducing these risks.

Analysis of Drivers and Pressures using the DPSIR framework provides context for the catchment

The Drivers-Pressures-State-Impact-Response Framework is used by the European Environment Agency to assess environmental risks and interventions.

DPSIR analysis is useful in assessing risks and potential responses to impacts on natural capital. It is applied in this project to provide a high-level assessment of the key drivers and pressures in the CamEO catchment

Annex 1 provides further detail in the context of rain-fed, irrigated and livestock dependent land use systems.



Source: U.S. Environmental Protection Agency And European Environment Agency, DPSIR framework 2016

Risks and pressures on natural capital have been considered across a range of drivers

We undertake a more detailed assessment of soil degradation risks and pressures on CamEO

Table 17. **Potential drivers, pressures and risks faced in the catchment**

Driver	Pressures	State	Impacts	Responses
Political: agriculture and environmental policies	Food production (for domestic use and export)	Additional land used for crop production	Increase in fertilizer run-off	Higher water treatment costs
	Agri-environment requirement	Less agricultural land used for crop production	Reduced income from crops	Decrease in land used for farming
Economic: markets, incentives, resource costs	Change in eating habits	Supply chain pressures	Higher prices for vegetables	Increase share of land used for crop farming
Social: social preferences and behaviour, demographics	Population growth	Increased demand for public water supply	Reduced water available for irrigation	Explore alternate water source, change crop mix
Environmental: climate change, land and water use, natural asset degradation	Rainfall deficit	Low flow in rivers	Low crop yields	Explore other water source, change crop mix
	Soil degradation	Higher nutrient/sediment content in rivers	Increased water treatment costs	Reduce intensity of farming

Sources: Analysis based on Environment Agency, The Cam and Ely Ouse Management Catchment, 2014, ONS population forecast, Greater Cambridge, Greater Peterborough Enterprise Partnership Strategic Economic Plan

Soil degradation shows how specific changes in natural capital create costs for the overall catchment

Table 18. ***Case study*: Soil degradation**

Driver	Pressures	State	Impact	Response
Environmental: climate change, land and water use, natural asset degradation	Soil degradation	Higher nutrient/sediment content in rivers	Increased water treatment costs	Reduce intensity of farming

The remainder of this section presents an analysis of the impacts of soil degradation on natural capital and key ecosystem services in CamEO.

Soil degradation impacts are shown here to demonstrate how land use impacts natural capital, both locally and across the ecosystem.

Intensive farming activities, particularly in heavily farmed areas in the lower part of the catchment impact local water resources through sediment and nutrient runoff. The catchment's water flows carry these impacts elsewhere in the catchment, where they create off-farm costs related to water quality and flood risk. Losses in carbon stored in farm soils and greenhouse gas emissions from increased diesel and fertiliser use contribute to global climate costs.

Changes in on-farm soils management have potential to enhance natural capital and deliver benefits to a range of stakeholders through reducing these damage costs.

Soils provide valuable ecosystem services, including crop provisioning and water regulation

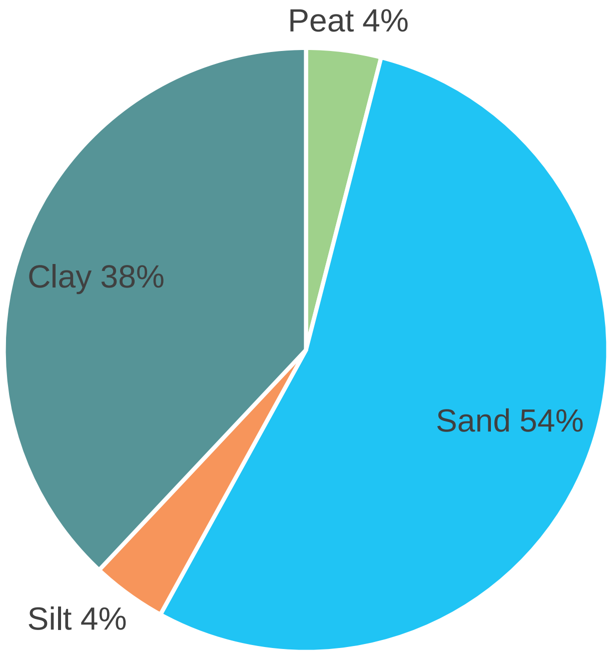
Soils provide ecosystem benefits by retaining moisture and nutrients that support growing crops (provisioning) and preventing quality-reducing runoff into waterways (regulating).

Given the long time scale for replacing soils, they are treated as finite, non-renewable natural capital assets.

Land use affects soil types differently; combined, these are known as *soilscapes* (e.g. horticulture + silt).

Soil degradation in this study is measured for **erosion** (loss of soil), **compaction** (reduction in quality of soil) and **loss of carbon** stored in soils, all of which reduce the services provided by soils.

Dominant soil type: Share of CamEO land area



Source: Cranfield University (2017)

Soilscapes analysis models on-farm and catchment-wide damage costs from soil degradation

To model the impacts of different land use activities on soils, we model the costs of degradation on the catchment's stock of soils, based on *soilscapes*.

– High-level values for soil erosion, compaction and carbon storage were applied to the catchment land cover for this analysis. This assumes degradation modelled at the national level is representative of CamEO soilscapes. No detailed local observations were gathered for this study.

Our approach yields on-farm damage costs to provisioning services (i.e. reduced crop output) and catchment-wide costs for regulating services (i.e. water quality impacts).

Damages from soil degradation include:

– Increased sediments in rivers and drinking water,
– Increased nutrient runoff in lakes, rivers and drinking water
– Reduced flood risk management from soils
– Reduced carbon stocks stored in soil
– Reduced crop output
– Increased fertilizer costs

Table 19. **Risks of soil erosion, by soilscape, England and Wales**

Land use	Soilscapes			
	Clay	Silt	Sand	Peat
Urban	L	H	H	n/a
Horticulture	L	H	H	H
Arable intensive	L	H	H	H
Arable extensive	L	M	H	H
Grassland improved	L	M	M	H
Grassland unimproved	L	M	M	H
Rough grassland	L	M	M	H
Forestry	L	L	L	M
Woodland	L	L	L	M
Wildscape	L	L	L	M

Source: Cranfield University (2015)
Note: Land classified as horticulture may include farmland considered in 'other cropping' or 'general cropping' elsewhere. Estimated values of erosion by soilscape are provided in the methodological appendix.

Soil degradation leads to greater run-off of sediments and fertilizer nutrients into water resources

Treatment costs provided for costs related to run-off from farmed land. Values are based on modelled estimates from UK-level data.

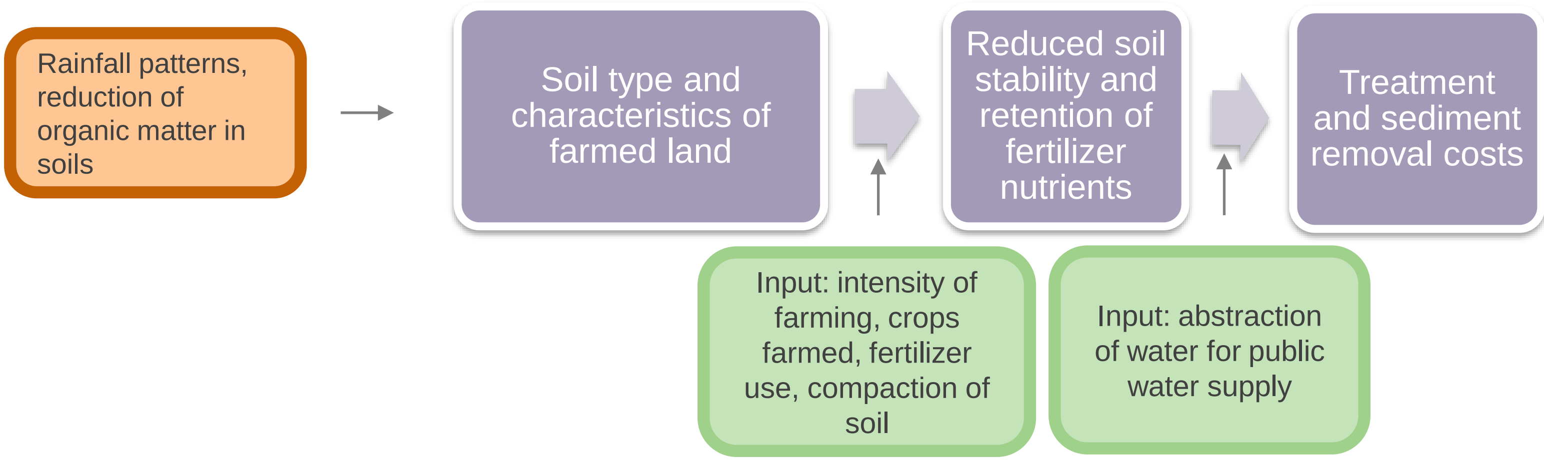


Table 20. **Value of water quality impacts from soil degradation in CamEO**

Water treatment cost	Catchment area (ha)	Estimated treatment costs (£/ha)	Value (£ million/year)
Removal of sediments in drinking water		15.5	5.1
Removal of sediments in rivers		5.2	1.7
Cost of N in drinking water	328,000	0.2	0.4
Cost of N in rivers and waters		1.3	0.4
Cost of P in lakes		2.5	0.8

Soil compaction increases flood risk across the catchment

Damage costs provided for additional flood risk caused by soil compaction on farmed land. Values are calculated from costs of soil degradation observed in CamEO from 2010-2016.

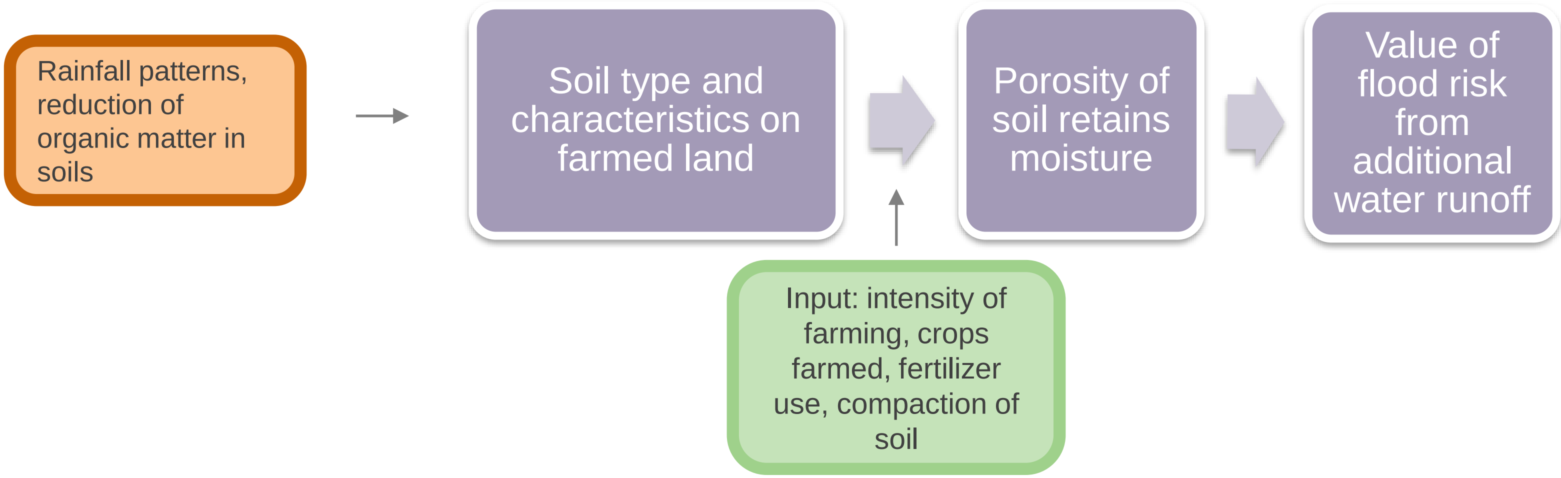


Table 21. **Value of increased risk to flooding from soil degradation in CamEO**

	Relevant area in catchment (ha)	Incremental flood risk costs (£/ha)	Value (£ million/year)
Flood risk reduction from soils	110,000	43.9	5

Source: Cranfield University

Soil degradation results in soil carbon loss and emissions of greenhouse gases leading to climate damage costs

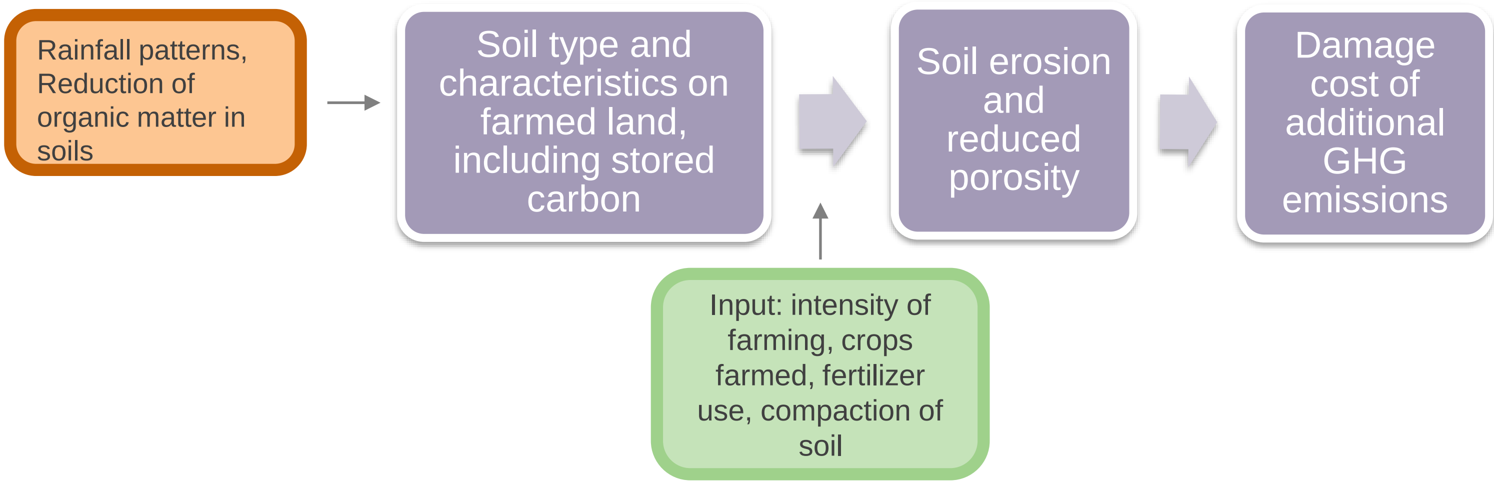


Table 22. **Damage costs from GHG emissions and storage reduction**

GHG cost	Catchment area (ha)	Damage costs (£/ha)	Value (£ million/year)
Soil carbon losses	328,000	15-25	5.9
GHG cost (NPK – replacement fertilizer)	328,000	0.8	0.3
GHG cost (NO_2)	328,000	6.6	2.2
GHG cost (NH_3)	328,000	0.3	0.1
GHG cost - diesel	328,000	1.7	0.6

Note: Values are estimated from costs of soil degradation modelled for UK and applied to CamEO

Soil degradation costs CamEO more than £39 million per year in damages and treatment costs

60 per cent of costs related to farm soil degradation impact off-farm services

Table 23. **Costs to ecosystem services from soil degradation (annual £m)**

	Food	Loss of stored carbon	Other GHGs	Water quality	Flood risk management	Total
Damages from soil erosion	4.6	1	na	8.3	na	13.8
Damages from soil compaction	11.5	na	3.1	0.2	5.0	19.8
Damages from loss of soil carbon	na	4.9	na			4.9
Total (£m/year)	**16**	**5.8**	**3.1**	**8.45**	**5.0**	**39**
On-farm costs	16	0.05				16
Off-farm costs	0	5.8	3.1	8.45	5	23

Notes: na: not applicable. The calculation method is explained in the annex. Onsite farm costs are already accounted for in the aggregate estimates of Net Profit to land.

Contents

Conclusions

The aim of the project is to provide a high-level assessment of the value of natural assets in the Cam and Ely-Ouse (CamEO) catchment and provides a proof of method for the application of natural capital accounting in a catchment.

Data is presented herein for a ‘central’ scenario. Values could range ± 25 per cent.

Natural capital in the CamEO catchment provides ecosystem services valued between £200m and £320m per year. The main sources for these benefits are recreation, water and food production with private households, Anglian Water and farmers as the beneficiaries. This is a partial assessment with some key services requiring a detailed modelling approach to be valued appropriately.

Analysis of the current costs of soil degradation using the soilscapes methodology demonstrates that erosion, compaction and soil carbon loss in this area reduce the potential benefits by about £39m per year. These costs are borne by farmers, the water industry and society as a whole with 60% of damage costs impacting off-site.

A catchment based approach to water and land management has significant potential. More detailed work is required to identify priority areas which address the social, environmental and economic challenges the catchment faces in the future. The next two slides set out three proposals for further work.

Three ways to extend the work

Offering either a comprehensive approach (1), or alternative, limited, focused analyses (2 & 3)

1. A catchment ecosystems strategy addressing current and future pressures

Benefits: develops an asset plan maximising the value of five key assets

- *ground water,* quality and volume
- *soils,* sustaining agricultural productivity
- *recreational space*, creating opportunity on the urban fringe
- *biodiversity*, resilience through scale and connectivity
- *surface waters,* compliance of with regulatory requirements

2. An ecosystem services opportunities map

Benefits: identifies measures which could enhance natural capital for people and biodiversity

3. Stakeholder focused opportunities maps

3.1 Water industry opportunities. Benefits: identifies measures which could complement or substitute for AMP7 waste water or WRMP19 water resources or treatment projects

3.2 Agricultural opportunities. Benefits: identifies measures to increase the natural capital value of land currently under agricultural production, informing agri-environment scheme design

3.3 Local authority opportunities. Benefits: identifies measures for enhanced amenity, health and flood risk management

Methodology for phase two

Building on phase one, phase two introduces additional tools for spatial planning

In addition to the phase one data sets and analysis, the phase two work would bring together various models and datasets to quantify opportunities and allow either optimised or scenario-based asset management plans to be developed. These are:

— Corine land cover maps together with Farmscoper database of agricultural measures to manage soils and diffuse pollution (publicly available)

— Soilscapes (Cranfield) to build an agricultural soils strategy

— JFLOW (JBA), SIMCAT and NRD (EA) database, allowing comparison of asset based solutions in the water industry and natural solutions to achieve Water Framework Directive objectives and water resources enhancements

— ORVal (publicly available) to estimate changes in recreational activity upon the creation of new recreational spaces

It combines these tools with asset management planning techniques, scenario building, economic metrics such as benefit cost ratios, return on investment and distributional analysis to identify attractive programmes and mechanisms for funding

Appendix 1: Natural Capital Accounts Methodology

The following sections provide more details of the methodology for this project covering:

- Natural capital accounting methodology and approach
- Classification of ecosystem services and mapping to priority services for CamEO
- Summary information and data sources on priority services in CamEO
- Valuation approaches for priority services
- Overview of methodology for assessing costs of soil degradation

Included in a separate Appendix 2:

1. Maps of catchment activity, natural capital assets and ecosystem services
2. Data tables supporting valuation and soilscapes scenario

Natural capital accounting – key aspects of methodology

Accounting framework	The structure of accounts is designed for practical use in the catchment to inform value of natural assets, risks to benefits and high-level potential to enhance values, informed by recent NCC guidance (1).
Categories of asset	Use broad habitats as the building blocks including: woodland, enclosed farmland, freshwaters. Opportunity to apply Cranfield's 'soilscapes' typology (which brings together land cover, soil type, agricultural grade and land values). Soil, water and biodiversity assets important constituents of these ecosystem assets.
Categories of services and benefits	Scope priority ecosystem services using long list from CICES ecosystem services classification (2). Initial prioritisation linked to evidence on benefit flows important to catchment.
Distribution of impact	Use of GIS spatial mapping in accounts where feasible. For valuation, identify key beneficiaries and impact groups.
Time period for accounts	Suitable most recent annual data with qualitative assessment of future service flows over 50 years linked to qualitative assessment of risks. Where feasible, comparison with 5 year period to show recent changes over time.

Note: (1) Natural Capital Committee's How to do it: a natural capital workbook *(2017)*
(2) European Environment Agency Common International Classification of Ecosystem Services, includes provisioning, regulating and cultural services

Scope priority ecosystem services using long list from CICES ecosystem services classification

The Common International Classification of Ecosystem Services (CICES) sets out a potential standard to be followed. It is based on the well-established split into provisioning, regulating and cultural services. It should be regarded as a checklist rather than as a standard to be followed in all its detail.

Table 5.1 a: List of natural capital provisioning services to be considered in the UK accounts

	Description of service	Notes
Biomass ✓	Cultivated crops including horticulture (tonnes)	For example wheat; can include residues used as animal fodder.
✓	Grass (tonnes)	Livestock is excluded as the production of grass fodder is taken as the service.
	Wild fish (tonnes)	Aquaculture is treated in the same way as livestock.
✓	Woody biomass (cubic metres)	Production of timber
	Wild produce (tonnes)	Nuts, berries, mushrooms, wild animals
	Peat (tonnes)	For either horticulture or energy
Water (cubic metres) ✓	Water (cubic metres)	Water abstracted, including groundwater and collected water Naviagation Possibly
Energy	Hydropower (joules)	Energy from hydropower
	Other renewable sources (joules)	Energy from wind, solar, tidal etc.

Source: Office for National Statistics

✓ = priority service for Cam-EO catchment

Scope priority ecosystem services using long list from CICES ecosystem services classification - 2

Table 5.1 b: List of natural capital regulating services to be considered in the UK accounts

	Description of service	Notes
Mediation of wastes and nuisances	Air pollutant absorption by vegetation (tonnes)	Deposition of pollutants on bare soil is excluded
	✓ Other waste remediation (tonnes /cubic metres)	Solid waste e.g. manure spreading
		Liquid waste e.g. effluent deposition/dilution /remediation (may be a supporting service to water provisioning)
	Noise mitigation (decibels)	Shelter belts along motorways
	Mediation of visual impacts	Shelter belts around industrial structures
Mediation of flows	✓ Flood protection (cubic metres/ reduced risk of flooding)	Water absorption and attenuation by vegetation
		Control of sediment
		Provision of storage for excess water
	✓ Maintaining baseline flows for water supply (reduced risk of drought)	Supporting service for water provisioning
	✓ Storm protection (reduced risk of damage)	Properties protected by natural sea defences (wetlands, dunes, shelter belts)
	✓ Erosion protection (reduced risk of loss of soil)	Mass stabilisation and control of erosion rates
Biophysical Maintenance	✓ Greenhouse gas sequestration (tonnes)	Excludes carbon storage
	Local climate regulation	Vegetation that enables air circulation
	Pollination	Commonly seen as a supporting or intermediate service

Source: Office for National Statistics

✓ = priority service for Cam-EO catchment

Scope priority ecosystem services using long list from CICES ecosystem services classification - 3

Table 5.1 c: List of natural capital cultural services to be considered in the UK accounts

	Description of service	Notes
Physical interactions with nature	✓ Setting for outdoor recreation (No. of visits, or time spent at site)	Walking, hiking, climbing, boating. Note that health is generally viewed as a benefit rather than as a service
	✓ Nature-related tourism (No. of visits, time spent at site)	Bird watching, snorkelling
	✓ Amenity (experiential interactions with nature)	Overlaps with recreation; can include an element of option value.
Intellectual interactions with nature	Educational interactions (No. of visits)	School trips
	Subject matter for scientific research (No. of publications)	Research related to ecosystems
	Heritage preservation (cultural archive)	
	Ex situ entertainment viewing	Documentaries on UK ecosystems
	Sense of place / artistic representations	
Spiritual interactions with nature	Symbolic (emblematic plants, animals etc.)	No obvious measures within the UK
	Sacred and religious	
	Existence and bequest	

Source: Office for National Statistics

✓ = priority service for Cam-EO catchment

Priority provisioning and cultural services in Cam-EO catchment include agriculture, drinking water provision and environmental habitats

Table A1. **Priority provisioning services in CamEO catchment**

Provisioning services	Details
Food	Agriculture is a major economic activity in the region and the catchment produces a significant share of the UK's sugar beets, potatoes and vegetables. Livestock is also raised in the area.
Timber	Woodland accounts for around 10% of habitat type in Cam-EO and Thetford Forest is largest man-made lowland forest in UK which Forestry Commission manages as a sustainable working forest with important role in supplying British timber market.
Drinking water	Includes 2 important aquifers: Cam-EO Chalk and Woburn Sands important for drinking water supply, irrigation and valuable base flows but Chalk groundwater vulnerable to rising nitrate levels.

Source: Environment Agency (2014); Cranfield University (2015)

Priority regulating services in Cam-EO catchment include water purification, soil protection and climate regulation

Table A2. **Priority regulating and cultural services in CamEO catchment**

Regulating services	Details
Water purification (waste remediation)	Pollutants such as excess nutrients, and sediment are processed and filtered out as water moves through wetland areas, forests, and riparian zones. This purification process provides clean drinking water and water suitable for industrial uses, recreation, and wildlife habitat.
Flood and storm protection	Woodland and lowland fen provide flood protection to population areas including Cambridge and Ely.
Water supply flows	Maintaining baseline flows for water supply - more of a supporting service for water provisioning services.
Erosion protection	Soils play important role for supporting agriculture in region. Soil erosion is mainly confined to particular soilscapes, mostly on lighter arable soils on hillslopes and of peats in upland areas.
Climate regulation	Soil and vegetation sequester carbon and other greenhouse gas emissions. Woodlands sequestration of carbon.
Cultural services	
Existence (non-use) value	4 Special Areas of Conservation, 1 Special Protection Area and 120 SSSIs; unique chalk stream and lowland fen habitats, which bird populations depend on. Other values of biodiversity captured through underpinning role in delivery of ecosystem services.
Recreation	National trail, Woodland and Parks are located within catchment. Water recreational values can also be very important.

Source: Vivid Economics

Scoping data sources for physical and monetary assessment of natural capital assets

This table provides a list of potential data sources for use in the natural capital accounts although it was not possible to use all these sources in this project.

Table A3. **Data sources for natural capital asset measurement and valuation**

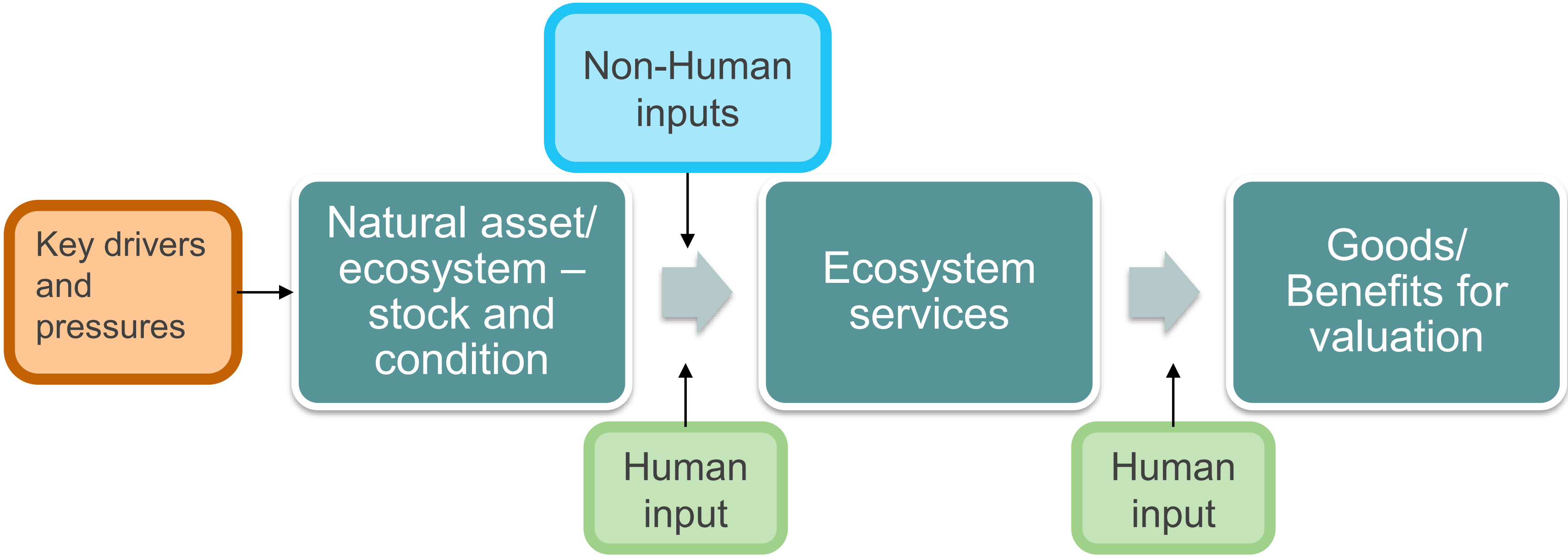
	Details of data and use in accounts	Available for spatial mapping?	Source
Natural capital asset (physical including measures of condition)			
Land cover	Quantify: Area of different habitats Value: replacement value of habitats	✓	LandIS; NERC CEH
Water quantity or flow	Quantify: areas where flows are below healthy level Value: Abstraction values	✓	Environment Agency; Ordnance Survey, Anglian Water
Soil indicators	Quantify: carbon content, water content Value: carbon price	✓	LandIS, Wasim model
Biodiversity indicators	Quantify: Abundance, mean species richness, ecological status of protected areas Value: stated preferences	✓	National Biodiversity Network; The Rivers Trust
Management practices	Quantify: Agri-environment uptake Value: Abstraction values	✓	Wasim
Existence value	Quantify: area of protected areas in catchment Value: stated preferences	✓	Natural England; The Rivers Trust

Data sources are provided for physical and monetary assessment of ecosystem service flows

Table A4. **Data sources for ecosystem service flow measurement and valuation**

	Details of data and use in accounts	Available for spatial mapping?	Source
Ecosystem service flows			
Crops harvested	Quantify: Quality of fisheries, tonnes of agricultural crops Value: residual resource rents	✓	Defra
Water abstracted, tonnes m3	Quantify: water abstracted for irrigation, drinking water, transfer to downstream users Value: Abstraction value		Wasim
Drinking water quality	Quantify: Phosphorous levels, Nitrate pollution Value: Damage costs		Environment Agency; Defra MAGIC
Climate regulation	Quantify: Tonnes C sequestered Value: Non-traded carbon price	✓	Natural England
Air quality	Quantify: PM10 absorbed by habitats Value: Damage costs	✓	Defra; HMT
Recreation	Quantify: Public use of lands and waters Value: Travel costs, stated preferences	✓	Natural England

A logic chain approach structures natural capital account development



- ONS-Defra paper on natural capital accounting principles highlights as good practice to set out a logic chain in developing accounts for ecosystems services. (ONS-DEFRA 2014)
- Logic chains provide a practical approach to integrating the analysis of key drivers and pressures. For example, it can provide a basis for appraisal of how changing the key pressures on a natural asset can feed into improving ecosystem service flows and benefits.
- **We have adopted a logic chain approach for each priority service included in phase 1 of the project.**

Ecosystem services are valued by both monetary and non-monetary methods

Table A5. **Approaches to economic valuation of selected ecosystem service**

Cultivated crops	Residual resource rent: used to isolate the resource rent attributable to the natural asset itself from the gross output. Use ONS guidance for calculations. However, use of the method may result in very small or even negative resource rents.
Water provisioning services	Residual resource rent for public water supply. Use ONS guidance for calculations. Complement with values for use derived from UK NEA.
Flood risk	Damage costs avoided from reduced flood risk. This is an area of further research. A particular challenge is that the probability of the service being provided varies across catchments depending on the risk.
GHG sequestration	UK 'non-traded' carbon prices published by BEIS. Existing fledgling ecosystem carbon markets (e.g. based on UK Woodland Carbon Code) are not suitable because they are sensitive to the wider institutional framework around carbon markets.
Outdoor recreation	Observed travel costs based on MENE can be interpreted as the price of access, together with admission and membership fees. Potential to use web-based recreational valuation tool, OrVAL.

Methodology to valuing water abstraction provisioning services

Table A6. **Water provisioning services – abstraction of surface and groundwater for drinking and other water uses**

Step 1	Collate data on the annual volume of water abstracted from surface water and ground water resources in the CamEO catchment (source: EA data). This provides a breakdown of abstractions for different uses: agriculture, water supply, industrial, commercial and public services, production of energy, amenity, and environmental. Environmental includes use in relation to river/wetland support, transfer between sources and pollution remediation. Amenity use includes water used for parks, golf courses, swimming pools, etc.
Step 2	Apply unit values for water abstraction to quantify the monetary flows of water abstractions. The range for unit values are based on a combination of resource rents and values for use in different sectors. The resource rent for water is the value after all human inputs have been subtracted, in practice gross operating surplus minus user costs of produced assets. A Defra report [2015] calculated unit resource rents, £/m3, to apply to public water supply abstraction in England & Wales. This is supplemented by abstraction values by different uses from UK NEA [2011] updated to 2017 prices. Environment NEA values based on WTP value of freshwater left in situ in the natural environment.
Step 3	Multiply drinking water abstractions, m3, by unit values, £/m3 to obtain estimated annual value of water abstractions by different water uses in CamEO. Water abstracted for agriculture is reflected in crop provisioning values so although presented in the water abstraction value table is not included in the total value of ecosystem service flows as it would be double-counting.
Step 4	Apply sensitivity analysis for value of drinking water provision in particular by cross checking with Anglian Water specific cost data on abstraction for public water supply.

Methodology for valuing the recreational benefits of natural assets

In this study, the value of natural capital assets used for recreation (aka the 'direct use value') are estimated using the ORVal recreation demand model developed by the University of Exeter.

This model applies a discrete choice approach to measure the value individuals place on recreation sites, measuring user preferences over a national dataset of visits and travel distances (the Monitor of Engagement with the Natural Environment survey). This data is gathered via face-to-face surveys of 50,000 greenspace users annually from across England and Wales.

Discrete choice valuation measures the additional utility a user places on a recreational asset by comparing the distances of further sites they are equally willing to visit (i.e., both a high quality proximal site that is chosen with the same frequency as a lower quality distant site are valued by the travel costs of the most distant site). ORVal draws on six years of data to estimate statistical relationships between different qualities of recreation sites (land cover including rivers and lakes, designations, points of interest) and willingness to pay amongst users.

The model applies these statistical relationships to estimate the number of likely visitors to a site, based on the population of areas at different distances from the site and the quality of the recreation asset. Travel costs and value of visitor time are estimated as a function of travel distance from the site, average cost of fuel and DfT values of time spent travelling for non-work purposes.

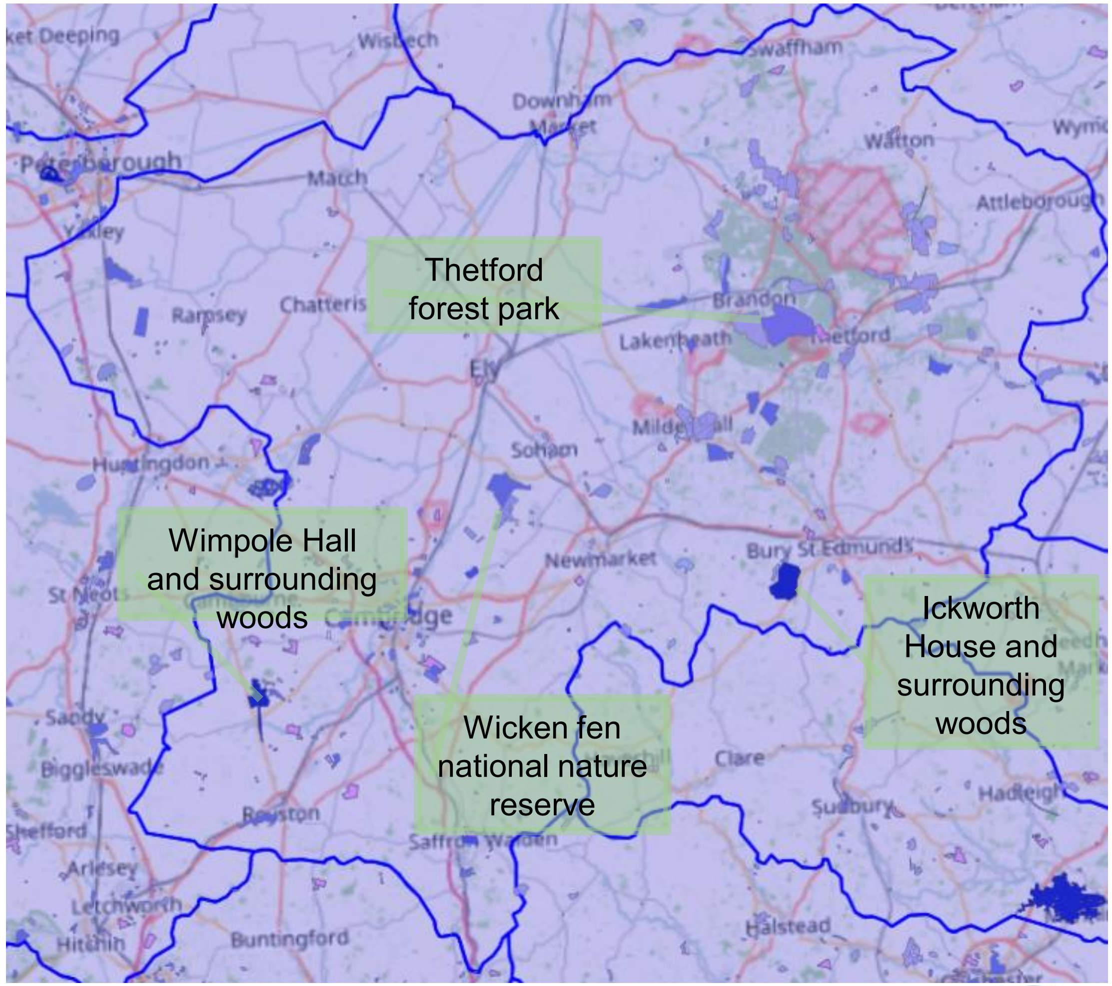
ORVal produces an estimate based on a large random national sample of the travel costs for each recreation asset in the catchment. By applying recreation preferences based on quality of land cover and designations like National Park, the model considers local users as well as travellers.

Source: Day & Smith (2017)

OrVAL Recreation model: Results for CamEO

Welfare Values (£ per year)

- Less than £30,000 (Low)
- £30,000 to £150,000
- £150,000 to £500,000
- £500,000 to £1 Million
- £1 Million to £5 Million
- £5 Million to £10 Million
- £10 Million to £20 Million
- Greater than 20 Million (High)



Source: Outdoor Recreation Model (ORVal), 2016

Treatment of biodiversity within natural capital accounts

Biodiversity underpins ecosystem service values although cultural values can be included

1 Background context

- Biodiversity can be seen as a supporting service to other services insofar as it is critical to the functioning of the ecosystem as a whole.
- Species diversity and abundance should be considered as characteristics of ecosystem assets, with declines in diversity and populations usually reflected in declines in the condition of ecosystem assets.

2 Methodological issues

- Aspects of biodiversity can be viewed as services, but in general the value of biodiversity will be captured via the value of the ecosystem services that each ecosystem asset produces.

3 Ecosystem service valuations of relevance

- Biodiversity will underpin ecosystem service valuation rather than provide direct biodiversity valuations
- Specific services of relevance are pollinating services and cultural values

4 Constraints within Solution space

- Identifying metrics that can link to biodiversity indicators to changes in ecosystem services for valuation

5 Proposed approach

- Use of biodiversity indicators (for example, abundance indicators, mean species richness). For the farmland ecosystem, a regularly updated index of specialist farmland birds is taken as an indicator for biodiversity. Also review WCMC guide (see below).
- Ensure no double counting of values - biodiversity values generally captured via ecosystem service flows although cultural values linked to wild species can be included.

6 Key data sources for taking forward analysis

- World Conservation Monitoring Centre has published a guide showing how to incorporate biodiversity indicators as part of NCAs
- 'Unnatural natural capital accounting' and NCC paper written by Colin Mayer addresses how to handle biodiversity in NCAs

Valuing biodiversity using cost-based proxies but these approaches need to be treated with care

Using a cost-based approach as an indicator of benefits of natural assets for no net loss target

Table A7. **Replacement costs for land cover in CamEO**

Land Cover Type	Catchment Area (ha)	Replacement Costs (£/ha)	Total Value, £m
Woodland - Broad leaved, mixed and yew	20,368	3,000	61
Woodland - Coniferous	16,500	2,500	41
Enclosed Farmland - Arable and horticulture	238,205		-
Enclosed Farmland - Improved grassland	58,840	1,000	59
Semi-natural grassland - Rough low-productivity grassland	12,210	1,000	12
Semi-natural grassland - Calcareous grassland	6	1,000	0
Semi-natural grassland - Neutral grassland	2,705	1,000	3
Water – Fen, marsh and swamp	222	8,250	2
Water - Freshwater	1,370	17,000	23
Mountains, moorland and heath - Dwarf Shrub heath	396	5,000	2
Mountains, moorland and heath - Inland rock	373		-
Coastal margins - Supra-littoral sediment	5		-
Urban - Built up areas and gardens	17,652		-
Total			203

Source: Vivid Economics, Cranfield University based on data from CEH Land Cover Map 2007 Dataset

Notes: replacement costs exclude land purchase, see:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/411185/Cost_estimation_for_habitat_creation.pdf
These replacement cost values provide an alternative approach to valuing the natural assets of the CamEO catchment and for that reason we are not including these values in the main analysis.

Drivers and pressures: methodology for assessing the costs of soil degradation

The following section provides an overview of the methodology previously developed by Cranfield University using an innovative soilscapes approach to valuing soil degradation in the catchment.

The aim of this assessment is to estimate the total economic cost of soil degradation in CamEO with a focus on the following soil degradation risks: erosion, compaction, and decline in organic content, (other soil degradation risks include: loss of soil biota, diffuse contamination and surface sealing).

An ecosystem services framework was used to assess how degradation affects the capacity of soils to support provisioning services such as food and fibre production, and regulating services associated with water quality, flood control and climate.

Emphasis was placed on the generation of ‘final goods’ that are of value to people, distinguishing between onsite and offsite costs, and market and non market effects.

For a detailed background of the approach see: The total costs of soil degradation in England and Wales A.R. Graves, J. Morris, L.K. Deeks, R.J. Rickson, M.G. Kibblewhite, J.A. Harris, T.S. Farewell, I. Truckle in Ecological Economics, 2015

Soilscapes consider differences in erosion across soil types and land use

Table A8. **Erosion rates for soilscape type category (t/ha/year)**

Land use	Soilscapes			
	Clay	Silt	Sand	Peat
Urban	0	10	5	0
Horticulture	2	20	5.1	15
Arable intensive	1.9	22	20	20
Arable extensive	1	6.3	3.5	10
Grassland improved	0.36	6.3	4.1	7
Grassland unimproved	1.3	4.5	1.5	10
Rough grassland	0.05	2.1	0.22	10
Forestry	0.01	0.75	0.05	0.7
Woodland	0.01	0.5	0.05	0.7
Wildscape	0.01	0.5	0.05	0.7

Source: Graves, Morris et al (2015)

Method to calculate the soil erosion costs

Loss of economic value of soil dependent ecosystem services and the cost of measures to substitute for or mitigate the degradation of soil underpins the costs of soil erosion.

17% of arable soils show signs of erosion in any one year with 40% being considered at risk. Total grassland areas subject to erosion was assumed to be 5% on improved grassland and 2% on rough grassland. The area of other soilscapes (urban, forestry, woodland and wildscape) considered to be liable to erosion each year was assumed to be 1%. These assumptions are based on the literature.

The annual erosion in England and Wales was calculated to be approximately 2.9 Mt/ha. The majority of this erosion was associated with silts and sands, especially on arable and horticultural land, where mean per hectare erosion rates were also highest. This loss was applied pro rata to the CamEO catchment.

The identified costs of soil erosion include:

i) on-site costs of the decline in agricultural and forestry yields caused by the reduction in soil depth, the cost of a reduction in the stock of carbon (C) due specifically to erosion, and the cost of losses of nitrogen (N), phosphorus (P) and potassium (K), and;
ii) off-site cost associated with impacts on environmental water quality, drinking water quality, and greenhouse gas regulation.

Method to calculate the soil compaction costs

Soil compaction is caused by vehicles, animals and human traffic.

The costs of compaction identified here include:

i) On-site cost of reductions in agricultural and forestry yields caused by impaired rooting medium and reduced water holding capacity, the extra draught power associated with ploughing and cultivation operations, and the cost of losing applied N, P, and K because of extra runoff; and

ii) Off-site costs associated with additional N, P, and K in the water environment, the greenhouse gas emissions associated with that loss and the additional requirement for draught power, and the additional flood damage associated with additional runoff.

The estimate yield loss was calculated based on the literature and expert opinion as a percentage of total yields, for England and Wales. This percentage loss was applied to the CamEO catchment land use for agricultural production.

Method to calculate the loss of soil carbon

The costs of loss of soil carbon were calculated by converting soil carbon lost into CO_2e measured at 1:3.67 ratio for soil C to atmospheric CO_2e. We applied the price for non-traded CO_2e as recommended by Government.

Table A9: **The estimated mean loss of organic matter (gC/kg soil/a) in each land use/soil type category**

Land use	Soilscapes			
	Clay	Silt	Sand	Peat
Urban	-0.10	-0.10	-0.10	-2.18
Horticulture	-0.10	-0.10	0.13	-2.18
Arable intensive	-0.10	-0.10	0.13	-2.18
Arable extensive	-0.10	-0.10	-0.10	-2.18
Grassland improved	-0.10	-0.10	-0.10	-2.18
Grassland unimproved	-0.68	-0.10	-0.68	-4.00
Rough grassland	-0.68	-0.68	-0.68	-2.18
Forestry	-0.68	-0.10	-0.68	-2.18
Woodland	-0.10	-0.10	-0.10	-2.18
Wildscape	-0.68	-0.68	-0.68	-4.00

Source: Cranfield University

References

Defra Principles of Natural Capital Accounting (2017)

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Company Profile

Vivid Economics is a leading strategic economics consultancy with global reach. We strive to create lasting value for our clients, both in government and the private sector, and for society at large.

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