The natural capital of floodplains: management, protection and restoration to deliver greater benefits

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The natural capital of floodplains:

management, protection and restoration to deliver greater benefits

Valuing Nature | Natural Capital Synthesis Report

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Floodplains are important natural capital assets which deliver a wide range of benefits to people. The interface between terrestrial and freshwater ecosystems in floodplains fosters both a wealth and a complexity of resources that are challenging to measure and compare.

Intensive agriculture covers nearly 70% of English and Welsh floodplains, compared to just 11% for species-rich habitats such as wet woodland, neutral grassland, fens and marshes. 42% of rivers have been deepened or embanked to such an extent that they are no longer connected to their floodplains. The benefits delivered by floodplain meadows, wet woodland, fen, and marsh are greater and more diverse than those supplied by intensively cultivated land. Management choices greatly affect the extent of the benefits delivered. A new agri-environment scheme option to support the nature-friendly management of floodplain habitats would promote the delivery of benefits, and should specifically facilitate:

- **Reconnection of rivers with their floodplains to allow them to flood and drain naturally;**
- **A shift of land use from intensive agricultural production to semi-natural habitats that can help to slow, store and filter water;**
- **Grassland management that promotes carbon and nutrient capture, and biodiversity supporting pollinating insects and biological control agents of pests and diseases.**

Key Messages

- **This review of scientific literature has shown that semi-natural floodplain habitats are a vitally important component of the UK's natural capital.**
- **They provide a wider range of goods and services than intensive arable/ horticultural crops.**
- **The dearth of such habitats in functioning floodplains reduces our resilience to floods and drought, reduces the abundance of pollinating insects and natural pest control agents, and reduces the potential for carbon sequestration and water quality improvements.**
- **Floodplains occupy only 5% of land area in the UK, yet targeted investment here would yield massive savings and gains for society as a whole.**

What is Natural Capital?

Natural capital is the sum of the assets within our natural environment that directly or indirectly provide benefits for humans. Plants and animals, freshwater, soil, air and oceans all contribute to natural capital.

Natural capital is a way of accounting for the amount of a resource we have (stocks), and the services that arise from these stocks (flows). These flows are either ecosystem services produced by living systems, such as crops and woodland, or abiotic services arising from geological processes such as water filtration and sediment capture. The value of an asset is a function of the benefits it provides, which can often be difficult to express in financial terms.

Natural capital assets are either renewable, providing benefits indefinitely so long as they are exploited sustainably, or non-renewable which means that they cannot regenerate within human timescales so can only be used once (for example peat). Natural capital assets are currently in decline and there is insufficient evidence to show whether our current patterns of use are sustainable[1].

UK-wide natural capital accounts are currently being developed for floodplains and semi-natural grasslands. Those for wetlands, farmland and woodland have already been produced[2]. There will inevitably be cross-over between the accounts for farmland, semi-natural grassland and woodland. These accounts show in simple terms:

1. **Extent:** the size of the area covered by each habitat in the UK
2. **Condition:** indicators of the quality of the habitat and its ability to continue supplying services
3. **Physical and monetary ecosystem-service flow:** quantity and value of services supplied
4. **Monetary asset:** value of the habitat, which reflects the total value of the services provided over the lifetime of the habitat.

These four accounts are crucial to ensure that we have the information to make informed choices about protecting or enhancing these assets in order to restore or continue to receive the benefits they provide.

What are floodplains and why are they important?

Floodplains are those areas of land adjacent to rivers which periodically flood; they are naturally capable of supporting a wide range of habitats. In the past, their use by humans was limited to management practices compatible with the natural flooding regime of the river. With both terrestrial and freshwater components, floodplains are complex systems. The interactions of hydrological, geomorphological, biogeochemical and ecological processes provide many ecosystem goods and services not obtainable from other landscapes.

We therefore depend on floodplains for many environmental goods and services. For example, floodplains have a widely recognised value in regulating flood events as they provide essential space outside the river channel for floodwater to occupy. They also store carbon in their deep alluvial soils, can support exceptionally high levels of biodiversity, capture sediment, absorb nutrients and filter water, whilst also delivering sustainable agricultural products with minimal inputs and constituting a rich cultural resource[3].

Floodplains cover over 1.6 million hectares in England and Wales[4] but just 3000 ha is occupied by species-rich floodplain grassland, with 8750 ha of alluvial forest and bog woodland. 42% of floodplains are no longer connected to the river system and do not contain land-use types typical of a fully functioning river floodplain[5]. The level of connectivity between rivers and their floodplain also varies considerably between rivers.

Floodplains are sometimes considered as a single element within the landscape, but because they are made up of different land uses (from semi-natural habitats to intensive agricultural land and urban areas), their sustainable management requires an appreciation of their complexity and dynamism.

Floodplain land use

Floodplain meadows were considered more productive and valuable than arable land, and were found throughout England according to the Domesday book of 1086.[6,7] Traditionally, seasonally flooded grassland provided a summer hay harvest followed by aftermath grazing. Where agricultural use was restricted by high summer water levels, wetter habitats such as fens, swamps and wet woodland would have occupied the floodplain. These provided important products such as willow for making baskets and hurdles, reeds and straw for thatching.

Land drainage and flood alleviation schemes have substantially changed land use in floodplains, allowing considerable expansion of intensive agriculture and urban development. It has been estimated that at least 42% of former floodplains are no longer in hydrological connectivity with their rivers and are therefore no longer able to function hydrologically as floodplains. Current estimates of floodplain land use in England and Wales indicate that nearly 70 % is under intensive agricultural use (arable and horticultural crops, or intensive grassland), whilst a mere 11% supports semi-natural habitats[5].

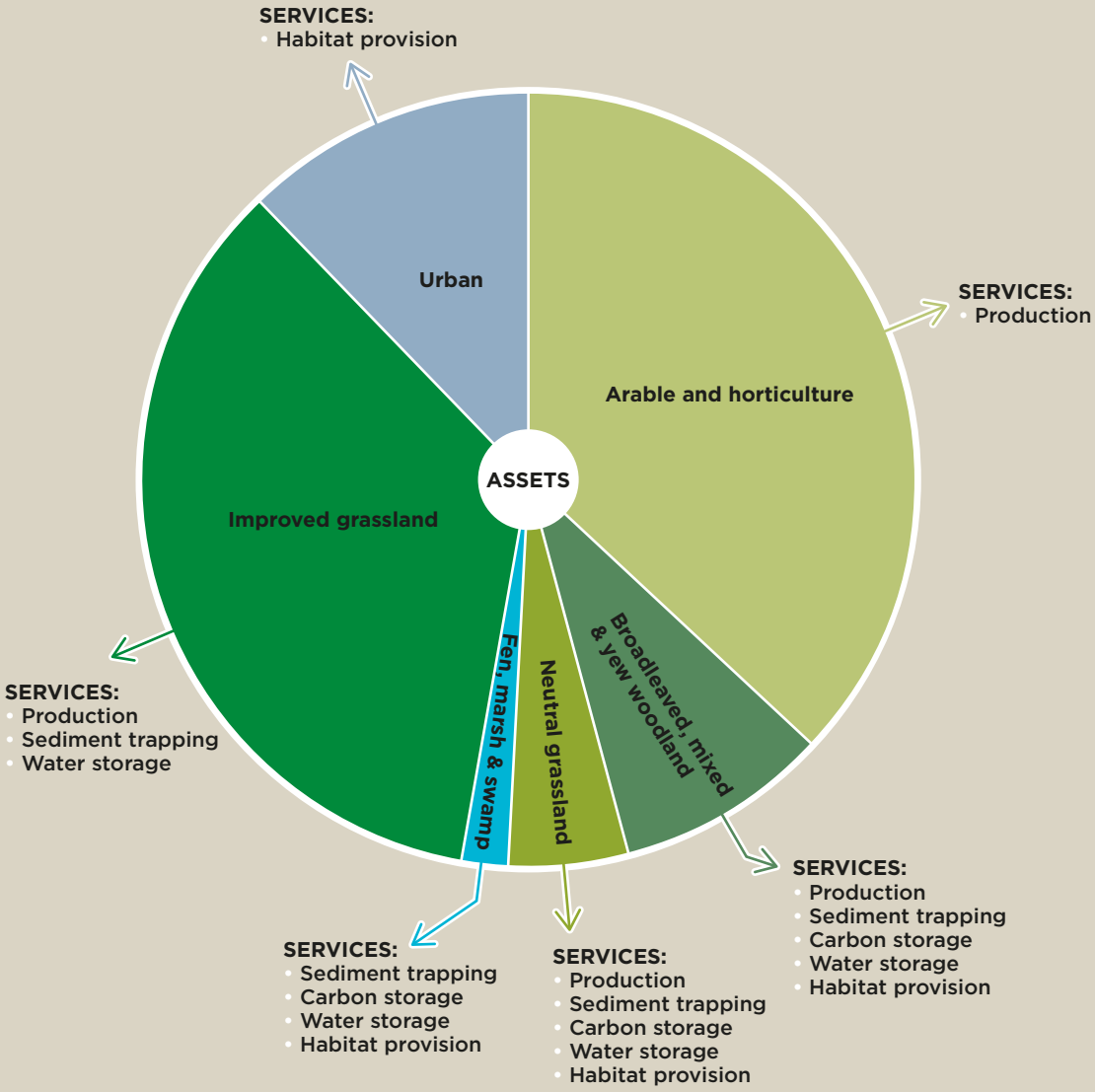
These remaining habitats provide a reminder of the traditional, rural landscape which typified the previous thousand years of British history. They have a critical role to play in the conservation of our natural and social heritage, and should be restored to provide more benefits such as adaptation to the effects of our changing climate.

Natural capital of floodplains

The stock of natural capital in floodplains depends on land use and land management. For example, arable soils have a much lower soil carbon stock than woodland or grassland[8];

These comparisons are reflected in the amount of benefit the different land uses provide **(Figure 1).**

Figure 1: Schematic diagram showing how natural capital assets in English floodplains are translated by providing services into benefits.



We have chosen, in this review, to focus on six land-use types **(Table 1.)**. These are the most extensive ones within floodplains based on the land-use categories provided by the CEH Land Cover Map 2015.[9] In this broad land cover classification, agricultural land and woodland are each divided into two categories. Neutral grassland includes both unimproved and semi-improved species-rich grasslands, while Fen, Marsh and Swamp covers purple moor grass and rush pastures, fens and reedbeds.[10] For the rest of the paper, we have removed references to yew woodland in the broadleaved, mixed and yew woodland land use type, as it does not occur in floodplains. Relative proportions of the chart are based on figures for selected land-uses in English floodplains[5]

Comparison of ecosystem goods and services provided by the land uses found within floodplains

Table 1 shows that seasonally inundated grasslands, fens and wet woodlands support diverse vegetation communities which deliver significantly more benefits than land used for arable and horticultural crops.

Table 1: Ecosystem goods and services provided by the Broad Habitats found within floodplains.

Ecosystem service provided by floodplains	Description of the environmental or social goods and services	Land Use					
		Arable and Horticulture	Improved Grassland	Broadleaved and mixed Woodland	Coniferous Woodland	Neutral Grasslands	Fen, Marsh and Swamp
Food	Agriculture; crop and livestock production	+	+			+	
Fibre	Timber production, reeds & osiers			+	+		+
Mitigation of climate change	Carbon sequestration and storage	–		+	+	+	+
Pollination of crops	Habitat for pollinating insects			+		+	+
Biological control	Nesting habitat for birds and bats as biological control agents			+	+		+
Water quality enhancement	Sediment trapping	–	+	+	+	+	+
Flood risk alleviation	Flood storage	+	+	+	+	+	
Conservation of genetic resource	Species-rich habitats – high diversity and rare species			+		+	+
Pollution control	Nutrient Management	–		+	+	+	
Maintenance of soil fertility	Soil development			+	+	+	+
Cultural history	Strong 'sense of place' and social history, nostalgia			+		+	+
Aesthetic	Enhancement of the landscape, intrinsic appeal			+		+	+
Recreation and health	Enjoyment of the outdoors, access to nature	+	+	+	+	+	+

Key: + identified as providing these goods and services
– negative or detrimental effect on ecosystem service

Many species-rich habitats (valued partly for their diversity and partly for the rarity of their component species) have been destroyed as a result of land-use change[11]. Traditional low-input farming systems are necessary for the restoration of these habitats. For example, species-rich floodplain meadows *Alopecurus pratensis – Sanguisorba officinalis* grasslands are managed by making hay followed by cattle and sheep grazing of the re-growth. Species-rich habitats have a vital role to play in the conservation of our natural and social heritage, and can provide a much wider range of ecosystem service benefits in floodplains such as pollination and biological control, than more intensive land-use types. As species-rich systems they also display greater resilience to environmental fluctuations and disturbances (e.g. drought, pests and diseases[12]).

Whilst production of food is predominantly through arable and horticulture, it is also provided through other more species rich habitats. Semi-natural grasslands still form part of a farming system. They are used for livestock production but at a lower intensity than improved grassland, requiring no chemical inputs and are less costly.

57% of grade 1 agricultural land in England is estimated to be within floodplains[13], although estimated agricultural production values in floodplains vary according to individual farm circumstances. Improved land drainage and flood management schemes have allowed floodplains to be used in this way, but flooding still occurs. The cost of flooding to agricultural production varies with estimated flood costs ranging from £80 ha^{-1} extensive grassland, £160 ha^{-1} improved grassland, £1100 ha^{-1} intensive arable and £4800 ha^{-1} horticulture for a single flood event (2010 prices)[14].

As arable, improved grassland and horticulture land uses reduce the provision of public goods, and have a much higher cost when loses through floods occur, a greater focus on other less intensive agricultural landuses contributes more overall when other benefits are taken into account, as the case studies show.

Placing a monetary value on ecosystem goods and services in floodplains

Whilst there is an intrinsic difficulty in ascribing monetary values to benefits that are not traded, there are a number of methods that can be employed. Willingness-to-pay or replacement-cost approaches are often used. A different approach based on energy-systems theory has been used to assess the value of the benefits provided by water, carbon and nitrogen[15].

A number of studies have attempted to value the natural capital of UK floodplains (e.g. **Case Study 1** Chimney Meadows).

It is important to take account of all services when making decisions regarding the most appropriate and sustainable land use. This is particularly relevant to floodplains where there is such a diversity of benefit types spanning both financial and non-financial benefits. **Table 2** shows some of the values used for different land uses in **Case Study 1.**

Table 2: Value in £/ha (2015 prices) of a selected number of ecosystem services and selected land uses. The monetary values are based on findings reported in Christie (2011)[16]

	Values in £/ha for benefits using method in Case Study 1		
	Water	**Sense of Place**	**Bio-diversity**
Lowland Meadow	197.2	203.4	499.0
Native Woodland	532.7	299.1	825.7[17]
Improved Grassland	197.2	203.4	177.4

Managing land management trade-offs on floodplains to deliver multiple benefits

Benefits delivered by floodplains are determined by hydrology, soil and land-management choices. Considering floodplain grasslands specifically as an example, where multiple management options exist, the matrix in **Table 3** shows how different management scenarios alter the extent of ecosystem-service delivery.

Table 3: How management changes affect delivery of goods and services in floodplain grasslands.
(all changes expressed relative to an extensive system of continuous grazing with mean sward height of 10 cm.)

Description of environmental or social goods and services	Management options			
	Supply of surplus nutrient via artificial fertilizers	Drainage designed to relieve waterlogging within three days	Sufficient stocking to maintain year round sward height below 5 cm	Harvesting hay at peak-protein (typically mid-June to first week of July)
Agriculture; crop and livestock production	↑	↑	↑	↑
Carbon sequestration and storage	↓	↑	↓	↑
Habitat for pollinating insects	↓	↑	↓	↑
Sediment trapping	–	↑	↓	↑
Flood storage	–	↑	–	–
Species richness	↓	↑	↓	↑
Nutrient capture	↓	↑	↓	↑
Soil development	↓	↑	↓	↑
Strong 'sense of place' and social history	–	↑	↓	↑
Enhancement of the landscape, intrinsic appeal	↓	↑	↓	↑
Enjoyment of the outdoors; health and well-being	–	↑	↓	↑

Key: ↑ increases benefit by taking the management action
↓ decreases benefit by taking the management
– no relationship

The management decisions as shown in **Table 3** reveal conflicts. For example, increasing fertiliser input increases productivity in the short to medium term, but decreases biodiversity, carbon storage, soil development and nutrient reduction. However, choosing management options that relieve waterlogging within 3 days and harvesting hay at peak protein can deliver positive services in all categories. An example of this management choice would be a floodplain meadow.

Application of principles in Government policy and practice relevant to floodplains

The Government's 25-year plan for the Environment (2018)[18] highlights the need to include delivery of public benefits in decision-making. The formulation of a new environmental land-management scheme will be critical in supporting landowners to manage their land differently so that it can deliver the benefits highlighted in this paper. The authors strongly recommend that a new land-management option specifically focussed on floodplains is developed as part of the forthcoming revisions to agricultural support, which should encourage:

- **Reconnection of rivers with their floodplains to allow them to flood and drain naturally;**
- **A shift of land use from intensive agricultural production to semi-natural habitats that can help to slow, store and filter water;**
- **Floodplain grassland management that promotes carbon and nutrient capture, and biodiversity supporting pollinating insects and biological control agents of pests and diseases.**

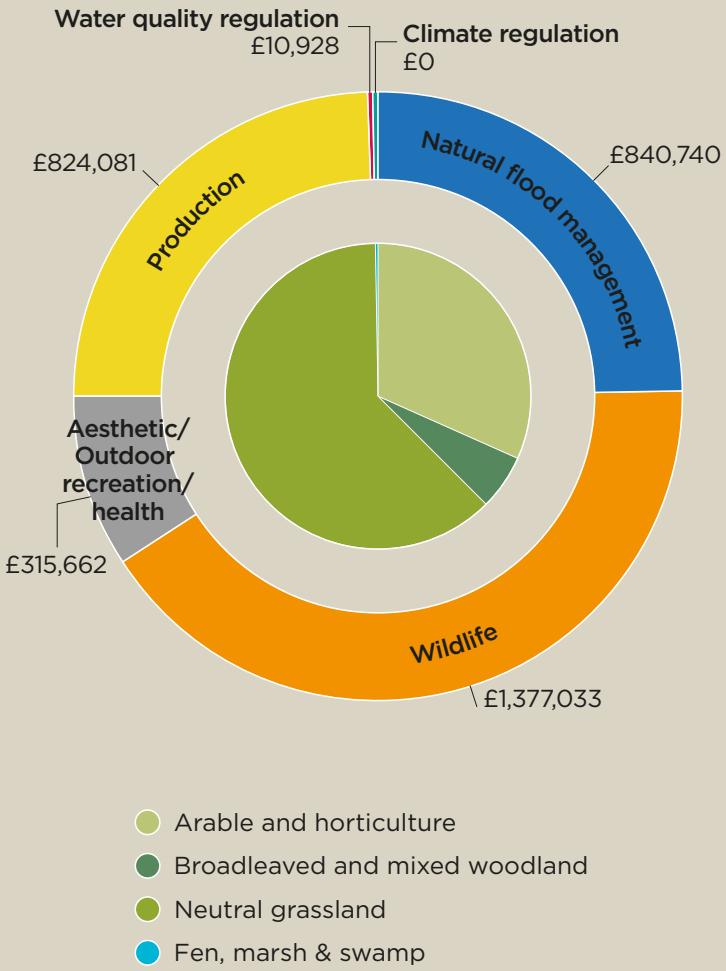
Three case studies are used to illustrate how different approaches to assessing natural capital can be used...

Case Study 1:

Chimney Meadows National Nature Reserve (NNR) – change in land use from a commercial arable and grassland farm to a nature reserve with floodplain meadows[19]

Chimney Meadows NNR is partly designated as a SSSI for its species-rich lowland hay meadows. It was purchased by the Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust (BBOWT) in 2003 as a 260 ha farm, which had been under predominantly intensive arable management. The vision was to restore the arable land to species-rich meadow and wetland habitats for wading birds. A comparison of the business as usual benefits (commercial farm) as opposed to those they hope to achieve through changes in management (nature reserve) was undertaken in 2017. This showed that the benefits realised through the nature reserve vision were worth £7 million more over 30 years than if the farm had been run as a commercial enterprise. **This is an additional value to the asset of 592%.**

Figure 2a: Costed benefits of commercial farm, capitalised over 30 years in **Case Study 1**



Case Study 2:

North Meadow National Nature Reserve (NNR) is a 44.4 ha floodplain meadow in Wiltshire (Figure 3).

Low intensity farming at North Meadow, Cricklade, delivers multiple benefits. © Mike Dodd

It has been assessed in a similar way to Chimney Meadows NNR in **Case Study 1 (Table 4),** but additionally calculating the natural capital value of the reserve. This calculation shows that the present asset value of the NNR taking into account a wide range of services shown in **Table 4** is £2,425,686, compared to an agricultural value alone of £1,277,428. **This is an additional value to the asset of 90%.**

Figure 2b: Costed benefits of nature reserve capitalised over 30 years refer to **Case Study 1**

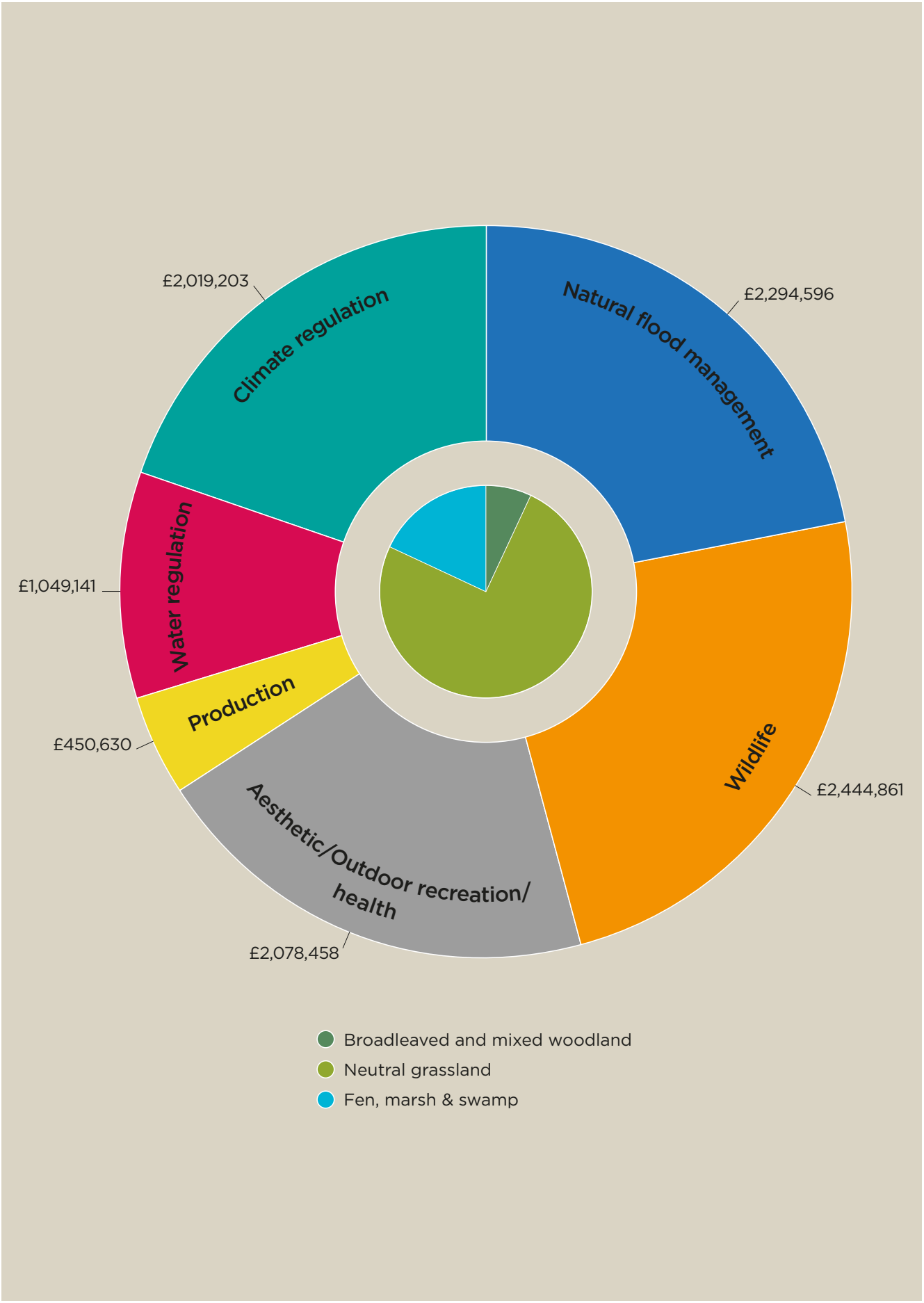


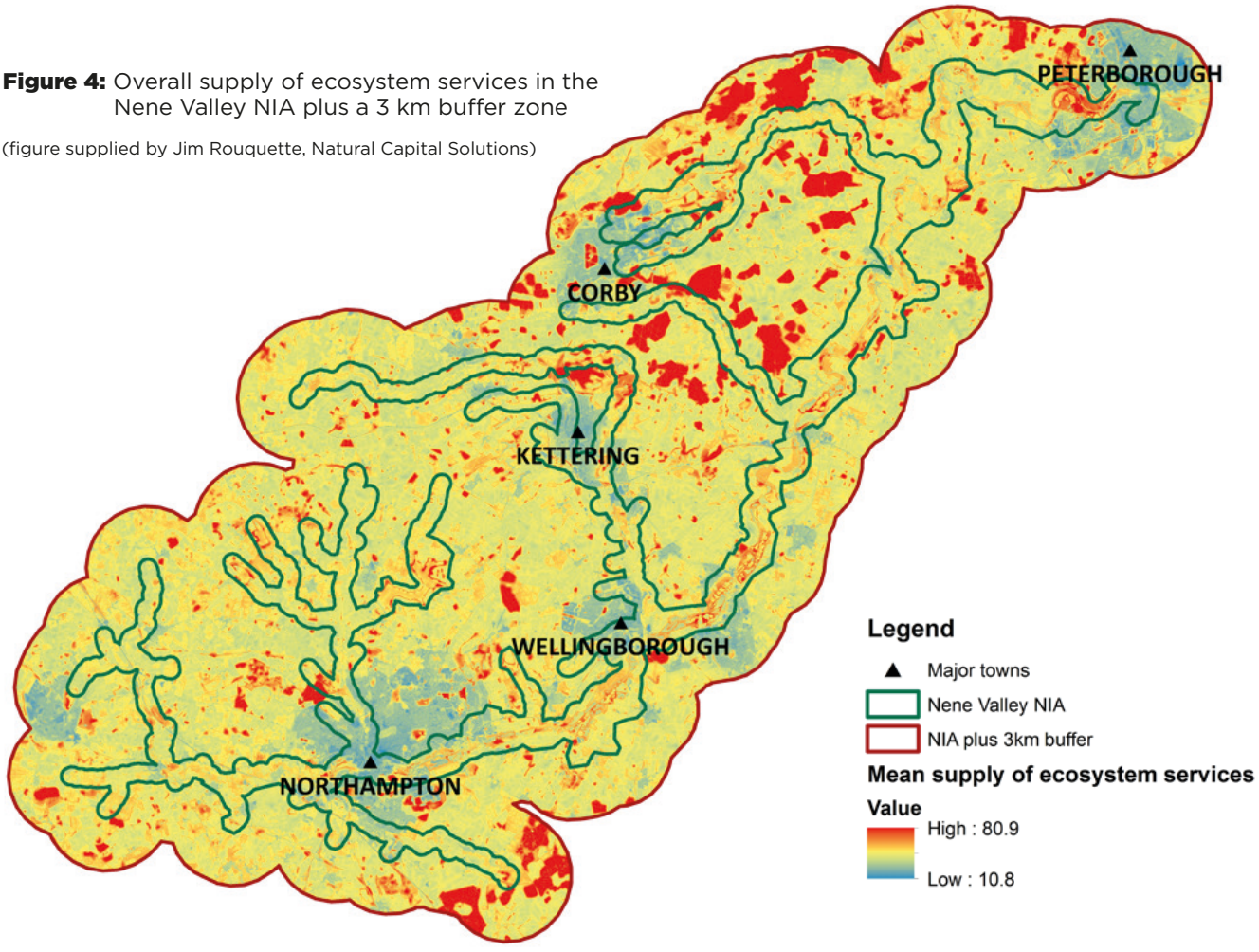
Table 4: Monetary values for North Meadow NNR, Wiltshire for a range of ecosystem services.

Benefit provided by floodplain	Description of the service delivering the benefit	North Meadow quantities	Value per unit	North Meadow total value
Food	Agriculture; crop and livestock production Hay values	Hay yield 4 t ha^{-1} yr^{-1}	Gross margin = £40/t	£6,216
	Grazing land value	0.4 LU ha^{-1}	£2.50 LU^{-1} $week^{-1}$	£375
Climate Regulation	Carbon sequestration (t/c/ha/yr)	Variable with season. Hay yield 4 t ha^{-1} yr^{-1}; Carbon content of 47.5% = 1.9 t C ha-1 yr^{-1} = 7.0 t CO_2e ha^{-1}	£66 tCO_2e^{-1} (DECC non-traded carbon price, 2018) £459.80 ha^{-1}	£20,415
Climate Regulation	Carbon storage below ground (soil, t c ha^{-1})	Soil carbon = 109.4 t ha^{-1} =4857.4 t C top 10 cm	No equivalent £ values	Not known
	Carbon storage (above ground tC ha^{-1}	Variable with season, no long-term store		£0
Pollination	Habitat for pollinating insects	44.4 ha	£29.14 ha^{-1}	£1,294
Water quality	Sediment trapping	0.8 m^3 ha^{-1}	£13.83 m^{-3}	£491
Air quality	Removal of atmospheric pollutants	No data		
Natural Hazard Regulation	Flood storage (above ground)	44.4 ha	£197	£8,746
Biodiversity	Species-rich habitats – high diversity and rare species	44.4 ha	£499 ha^{-1}	£22,156
Cultural history	Strong 'sense of place' and social history	44.4 ha of historic landscape	£203.4 ha^{-1}	£9,013
Aesthetic	Enhancement of the landscape, intrinsic appeal	No data		
Recreation	Enjoyment of the outdoors	15,000 visitors yr^{-1}	X £500 ha^{-1} yr^{-1}	£22,200
Health		2 km of path with 50 m wide buffer either side = 20 ha	£433 ha^{-1}	£8,660

Figure 3: North Meadow NNR, 44.4 ha of species rich, agriculturally productive, historically important, and highly visited floodplain meadow.

Figure 4: Overall supply of ecosystem services in the Nene Valley NIA plus a 3 km buffer zone

(figure supplied by Jim Rouquette, Natural Capital Solutions)



Case Study 3:

The Nene Valley Nature Improvement Area (NIA) and the use of detailed mapping to assess benefits and identify opportunities.

Natural capital and ecosystem services in the Nene Valley NIA were mapped in 2016[20]. This compared the ecosystem-service value of the NIA area to an area that included the NIA plus a 3km buffer zone.

Habitats, change in land use (including a recorded 95% loss in 80 years of semi-natural grassland) and biodiversity were mapped. Provision of ecosystem services was mapped based on an EcoServ GIS toolkit developed by The Wildlife Trusts, with modifications to suit the area. Bespoke models were created and applied at a 10 m x 10 m resolution, covering 10 services including the capacity to store carbon, provide noise abatement, local climate regulation, air purification, water flow, water quality, pollination, food production, tranquillity and accessible nature, along with the demand for those services. Financial values were applied to the ten services.

Overall, the area within the NIA delivered benefits worth £2639/ha compared to £1769/ha across the whole study area. The value of recreational visits far outweighed the value of other services provided by the Nene catchment. However, only a limited number of services were considered in terms of a monetary valuation.

The maps will be used for raising public awareness, and to facilitate land-use planning and ecosystem accounting. They identify where land use should remain as it is, and areas where a change in land use would be beneficial, for example close to watercourses, where measures can slow the flow of water, deliver biodiversity, improve water quality and provide other benefits at the same time.

Trade-offs were identified through the mapping process including between food production and all the other services. The study highlighted that the wider ecosystem services delivered through a variety of different land uses needs to be balanced against the maintenance of a strong rural economy and farmer livelihoods. The use of payments for ecosystem services was recommended as a way of facilitating both.

Evidence gaps

This review has used figures for land use in floodplains for England and Wales only. An analysis of floodplain land use in Scotland and Northern Ireland would complete a UK-wide assessment.

A variety of methods have been used to assess land use and extent of habitat type in floodplains. A consistent approach is required across all the nations to determine extent of key semi-natural habitats and overall floodplain land use.

Assessment of some individual habitat types or vegetation communities is required. An example is wet woodland, which although included within the broad land-use type of broad leaved and mixed woodland cannot be specifically distinguished due to the difficulty of mapping these small linear features.

Further research is required to better define ecological and biogeochemical processes at the habitat or plant community level to provide quantitative figures demonstrating their benefits. This is particularly true for estimates of carbon and water storage in soils, but also biological services such as pest control and pollination.

A better understanding of the effectiveness of floodplain restoration for natural flood management has been highlighted by the Environment Agency[21] as part of a review on the evidence for benefits of natural flood-management techniques. Areas where there are currently evidence gaps include an assessment of floodplain grasslands and their role in natural flood management.

It is clear there is an enormous potential to increase the extent of floodplain habitats that can provide us with multiple benefits, yet continue to sustain productive agriculture. The Floodplain Meadows Partnership, Forest Research and River Restoration Centre are working to promote the value of such habitats and to disseminate best practice knowledge of how to restore and manage them.

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The Valuing Nature Programme is a 5 year £7M research programme which aims to improve understanding of the value of nature both in economic and non-economic terms, and improve the use of these valuations in decision making. It funds interdisciplinary research and builds links between researchers and people who make decisions that affect nature in business, policy-making and in practice. See **www.valuing-nature.net**

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