

Blenheim Estate Natural Capital Assessment

Technical report

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Summary

The natural capital of the Blenheim Estate, including the woodlands, fields, gardens, lakes and other habitats, delivers significant benefits for the estate, the local community and visitors. Blenheim Park is well known for its outstanding cultural and historic value, attracting visitors from all over the world, but it is also highly valued by the local community as a special place to exercise, relax and connect with nature. The Park and the wider estate produce food, timber, fresh water and renewable energy, store and sequester carbon, and provide a flood protection service for communities downstream, as well as providing habitat for wildlife including pollinators and crop pest predators. There are opportunities to manage natural capital in a way that protects and enhances key services such as water quality regulation and erosion protection, and improves the connectivity of walking and cycling routes and wildlife corridors.

This natural capital assessment has estimated the value of the ecosystem services provided by the Estate in 2019. The assessment covers the whole 12,000 acre (4858 ha) estate, using readily available data. A more detailed level of assessment, including public participatory mapping of cultural ecosystem services, has been conducted for the 975 ha Blenheim Park, which forms a distinct area of high cultural and biodiversity value.

Natural capital assets

- **Farmland:** 3,595 ha, 75% arable and 25% improved grassland. Over 80% of the farmland is moderate agricultural quality (Grade 3 on the 5-point Agricultural Land Classification scale), with the rest being mainly lower quality Grade 4 land.
- **Woodland:** 736 ha, including 309 ha of ancient woodland. This includes 274 ha of semi-natural broadleaved, 326 ha of plantation (160 ha coniferous, 70 ha broadleaved, 96 ha mixed), 129 ha of unknown broadleaved, and 7 ha of traditional orchards.
- **Veteran and ancient trees:** 1282 trees in the woodland and in the wider parkland, identified by the Estate's veteran tree inventory and the Woodland Trust's ancient tree hunt (citizen science). These are mainly oaks (1008) but with some beech (149) and a few other species. They include four trees listed on the global Monumental Trees citizen science website, two of which are ancient oaks with a girth over 10 metres, and almost 200 trees with a girth of over 6 metres (diameter two metres). These trees have an estimated asset value (replacement cost) of £4.7 million in addition to their other benefits including carbon storage, biodiversity and sense of place.
- **Other semi-natural habitats:** 333ha, including 160 ha of wood pasture and parkland with scattered trees, 147 ha of semi-natural grassland (41 ha neutral, 26 ha calcareous, 2 ha acid, 78 ha marshy or unknown), 19 ha of scrub and 7 ha of wetland.
- **Amenity green spaces:** 22 ha of amenity grassland, 15 ha of domestic gardens, 2 ha of allotments or kitchen gardens and 1 ha of sports fields or recreation grounds.
- **Linear woodland features:** 135 km of hedgerows and 127km of lines of trees (including trees in hedges) or woodland strips along field boundaries.
- **Paths:** 72 km of public footpaths and 3.5 km of Sustrans off-road cycleways.
- **Water:** 28 km of rivers, 11 km of smaller streams and ditches, and 50 ha of lakes and ponds.

Ecosystem services

The Estate delivers a wide range of services, summarised in Table S1. Quantitative estimates of service delivery have been derived for food production, wood production, mineral water production, carbon storage and sequestration, flood protection, soil erosion regulation and recreation, though there is a high degree of uncertainty in many of these estimates. Monetary estimates have been provided for food production, carbon storage and sequestration and recreation. Qualitative information based on a public survey has been provided

for cultural ecosystem services. For the other services we provide scores on a scale of 1 to 10 to reflect the estimated ability of habitats on the Estate to deliver each ecosystem service. Key findings are below.

- **Higher scores than the Oxfordshire average:** Using a habitat-based scoring system, the Blenheim Estate scores slightly more per ha than Oxfordshire as a whole for all services except food production, and Blenheim Park scores almost double the Oxfordshire average for all services except food production and water supply (Table S2). However there is a noticeable contrast between the Park and the wider Estate, which is dominated by large arable fields that deliver food but have low levels of regulating and cultural services.
- **Food production:** Approximately 16,000 tonnes of crops are produced each year from the Estate (wheat, barley, oilseed, potatoes and others) with an estimated natural capital value of £615,000 (based on the whole farm income approach). The estate also produces an estimated 4,500 tonnes of grazed biomass.
- **Carbon storage and sequestration:** Approximately 454,000 tonnes of carbon are stored in soil and vegetation, worth approximately £32 million (using the 2020 UK government non-traded carbon price of £70.58/tonne carbon in 2019 prices). Approximately 1,400 tonnes of carbon are sequestered each year, worth around £100,000 annually.
- **Flood protection:** the vegetation on the estate averts an annual maximum flow of around 12,000 tons water per hour during storm events, providing protection from flooding for communities downstream.
- **Cultural services:** A face to face and online survey of over 1000 Park users found strong qualitative evidence that the park provides multiple benefits for physical and mental health, social interactions, and interacting with nature. There was particular appreciation for the wide open spaces, the freedom to roam around different contrasting areas, the beautiful scenery, the paved roads and facilities (café, toilets, play areas) which allow easy use all year round for families and less mobile visitors, the friendly staff and fellow visitors which enable social interactions, the variety of wildlife, the ancient trees, the lake and woodlands, and the sense of history and culture.
- **Recreation:** Using a travel cost approach, we estimate that the annual welfare value of the park to the 920,491 recorded visitors in 2018 was approximately **£4.3 million** (high uncertainty). The health benefits for the 223 survey respondents who visited the park for moderate to vigorous exercise at least once a week were estimated to be worth **£196,000 to £257,000 / year** in avoided healthcare costs (high uncertainty).
- **Education.** The Estate allows access to six woodlands outside the Park for seven regular Forest Schools or forest education sessions involving four local primary schools, one pre-school, one nursery, and a charity. These are estimated to deliver almost 20,000 student-hours of education per year, and are very highly valued by teachers and children.

Opportunities for enhancing natural capital on the Estate

There is a particular opportunity to enhance the services of erosion prevention and water quality regulation, at the same time as boosting carbon storage and providing biodiversity benefits and cultural value. Options that have been identified so far include:

- Restoring the over-grazed pasture in the north of the Park to semi-natural grassland, and converting some arable land to grassland in flood zones (e.g. in the Evenlode valley) or on steep slopes;
- Targeted tree-planting or natural regeneration, and introducing more hedgerows to subdivide some of the larger arable fields;
- Re-wilding in the Glyme and Dorn valleys (possibly introducing beavers to create wetland areas and meadows for flood control and wildlife habitat), and planting buffer strips and reed beds to improve water quality;

- Creating wildlife corridors to link into the Oxfordshire Nature Recovery Networks, where Blenheim is at a key junction between the Evenlode and Glyme valley networks and the Wytham Woods and Oxford Meadows networks to the south;
- Encouraging more sustainable agricultural management; and
- Enhancing the cultural and recreational value of the Park by providing additional paths and interpretation guides.

There may be opportunities to fund some of these schemes through voluntary carbon offsetting, biodiversity offsetting (planned to become mandatory for many development projects), agri-environment schemes or woodland carbon grants.

Table S1: Ecosystem service and biodiversity scores per ha for Blenheim Estate, Blenheim Park and Oxfordshire

	Score out of 10 per ha			
	Park	Estate not in Park	Whole Estate	Oxfordshire
Food production	2.10	3.53	3.24	3.47
Wood production	2.45	0.84	1.16	0.64
Fish production	0.59	0.06	0.17	0.11
Water supply	5.65	6.47	6.31	6.16
Flood regulation	5.33	3.03	3.49	3.02
Erosion protection	5.90	2.51	3.19	3.06
Water quality regulation	4.24	1.97	2.42	1.96
Carbon storage	5.09	3.01	3.43	2.97
Air quality regulation	3.22	1.77	2.06	1.57
Cooling and shading	5.11	2.92	3.36	2.66
Noise regulation	3.62	1.86	2.21	1.65
Pollination	4.43	2.58	2.95	2.68
Pest control	5.08	2.89	3.33	3.02
Recreation	2.81	1.57	1.82	1.73
Aesthetic value	6.34	3.18	3.81	3.51
Education about nature	5.47	2.58	3.16	2.61
Interaction with nature	4.89	1.97	2.56	2.24
Sense of place	6.66	3.02	3.75	3.25
Biodiversity	5.06	2.69	3.16	2.80

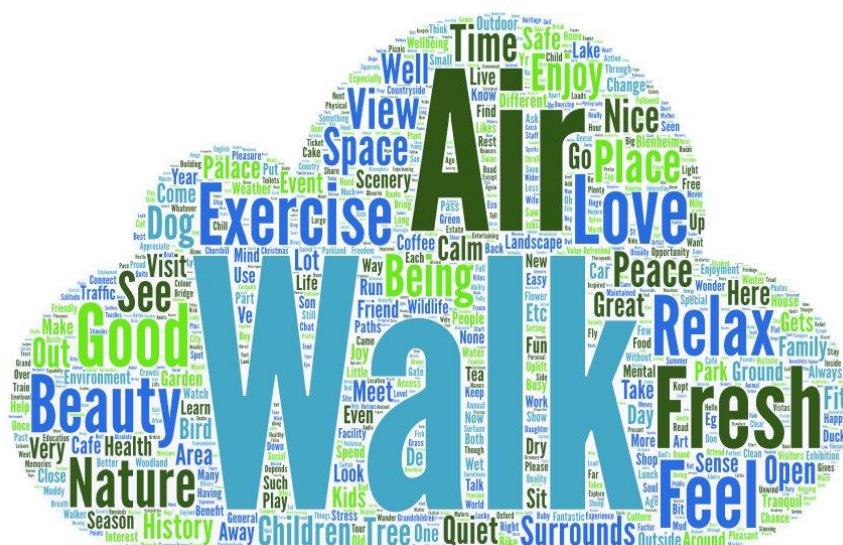


Figure 1 Word cloud of benefits that people get from visiting Blenheim (see Annex 2)

Table S2: Summary of ecosystem services provided by the Blenheim Estate

Assets	Quantity	Monetary value	Confidence	Comments
Crop production				
Blenheim Farm Partnership: 645 ha arable land; 513 ha managed by BFP, the rest by a contractor.	2628 tonnes (1489 t wheat, 780 t barley, 359 t oilseed)	Market value £459,536 Whole Farm Income £117,451	Quantity: High Monetary: High	From Farm Accounts: actual accounts for 2018. Whole farm income is the total income from agricultural production (excluding subsidies) net of costs (excluding taxes).
Whole Estate: 2,689 ha arable land.	16,000 tonnes (approx.) (wheat, barley, potato, oilseed, maize and other crops)	Market value £2,755,000 (approx.) Whole Farm Income £615,000 (approx.)	Quantity: Moderate Monetary: Low	Area of each crop estimated from 2019 RPA CROME data. Average yield of wheat, barley and oilseed estimated from BFP accounts. Other sources used for other crops. Whole Farm Income estimates from value per ha for the BFP (£229/ha) multiplied by the total arable area on the rest of the estate.
Grazed biomass				
Potential grazing land includes 906 ha improved grassland (incl. 386 ha in Blenheim Park), 147 ha of semi-natural grassland and 160 of wood pasture and parkland with scattered trees.	Estimated potential supply of grazed biomass for the whole estate is around 6,800 t/y (range 4,700 to 10,000 t/y) and the amount consumed by livestock is estimated to be around 2,100 t/y (range 1,200 to 7,800 t/y).		Low.	Estimates of grazed biomass production depend strongly on assumptions of yield per ha, which are highly uncertain. 1550 ewes and 40 cattle graze on the Estate, on the improved grassland, the semi-natural grassland and the wood pasture.
Wood production				
326 ha plantation (conifer, mixed and broadleaved) 396 ha semi-natural broadleaved, mixed or unknown woodland	Timber from productive forestry Prunings and thinnings from woodland management are chipped for wood fuel. Estimated potential extraction at 70% of annual increment is 2,600 m ³ .		Moderate	Based on estimated annual increment using assumed yield class. Could be valued using the ONS approach based on average price of £28.22 per cubic metre overbark for coniferous standing sales, but further information is needed.

Assets	Quantity	Monetary value	Confidence	Comments
Water supply				
Mineral water	1.4 million litres in glass and 1.98 million litres in cooler bottles per year sold via Love Water.	Operating profit £34,000 in 2019-20.	High	Operating profit is being used as a proxy for natural capital value
Surface water 28 km rivers; 50 ha lakes and ponds; Overall WFD status in 2016 was 13% bad, 17% poor, 70% moderate.	Quantity abstracted from surface water on or downstream of the estate is not known.			Reasons for not achieving good status include high phosphate levels from fertiliser runoff and sewage discharge.
Groundwater recharge 4783 ha unsealed surfaces (98.5%) Groundwater bodies have good quantitative status but poor chemical condition beneath 75% of the estate, good condition beneath 15% (the remainder has no groundwater body).	Score per ha (for groundwater and surface water): Estate 6.31 Park 5.65 (more woodland) Oxfordshire 6.16		Low	Indicative score based on habitat type. Reasons for not achieving good status include high phosphate levels from fertiliser runoff and sewage discharge but data is from 2013-2016.
Energy production				
Solar, hydro-electric, biomass	An unknown proportion of the estimated 2600 m ³ potential annual wood extraction will be used for biomass. Energy production not yet known.			
Carbon storage				
All estate habitats (hedgerows not yet included in the calculated quantities)	453,916 tonnes of carbon stored	£32,036,641	Medium	Based on UK non-traded carbon price for 2020 (£69.28 /tonne carbon)
Carbon sequestration				
All estate habitats (hedgerows not yet included in the calculated quantities)	1,412 tonnes carbon/year	£99,686/year	Low	Uncertainty over storage and sequestration rates for different habitats.
Air quality regulation				
1282 ancient and veteran trees (combination of Woodland Trust and Estate tree inventory)	490 kg/y pollution removed by the 1070 trees that had full data	£390/year	Medium	iTree-Eco valuation. Low value partly reflects the low background levels of air pollution in the area.
Woodland and hedgerows on the estate	Not yet quantified			

Assets	Quantity	Monetary value	Confidence	Comments
Flood protection				
1282 ancient and veteran trees (combination of Woodland Trust and Estate tree inventory)	Avoided runoff of 1,109 cubic metres/year by the 1070 trees that had full data	£2,263/year avoided stormwater treatment costs	Low	iTree-Eco valuation. Caveat: based on urban trees. Stormwater treatment costs are less relevant for rural locations.
All habitats on the estate (hedgerows not yet included in the calculated quantities)	Annual maximum of 12,390 tonnes water/hour of runoff averted		Low	Compared to bare soil. NatureTrade estimate, based on JULES hydrology model.
Soil erosion protection				
All estate habitats (hedgerows not yet included in the calculated quantities)	228 tonnes of soil erosion prevented . Score per ha: Estate: 3.19 Park: 5.90 Oxfordshire: 3.06		Low	Compared to bare soil. NatureTrade estimate, based on RUSLE equation.
Water quality regulation				
All estate habitats (hedgerows not included in the scores)	Score per ha: Estate 2.42 Park 4.24 Oxfordshire 1.96		Low	Indicative score based on habitat type. Score for the Estate is relatively low due to the high proportion of arable land.
Pollination All estate habitats (hedgerows not included in the scores)	Score per ha: Estate 2.95 Park 4.43 Oxfordshire 2.68		Low	Indicative score based on habitat type.
Pest control All estate habitats (hedgerows not included in the scores)	Score per ha: Estate 3.33 Park 5.08 Oxfordshire 3.02		Low	Indicative score based on habitat type.

Assets	Quantity	Monetary value	Confidence	Comments
Recreation				
Blenheim Park	920,491 visitors recorded in 2018, plus an unknown number of visitors entering on foot to use the public footpaths. 63% of respondents to the survey identified exercise as a benefit of visiting the Park.	Welfare value based on travel cost approach, £4.3 million/year	Low	It is not know how many of the 920,491 visitors experienced the grounds rather than just the indoor areas (Palace, shop and café)
Blenheim Park	270 survey respondents visit the park for moderate to vigorous exercise at least once a week, of whom between 132 and 174 would not get the same amount of exercise elsewhere.	Health benefits £196,000 to £257,000/year in avoided healthcare costs	Low	The survey may have captured many of the most regular visitors, but not all, so this is a conservative estimate
Blenheim Estate (Park plus 72km of footpaths and estate woodlands)	Estimated 1,985,468 visitors per year (Park 1,586,198)	£5.5 million/year (Park £4.7 million/year)	Medium	ORVal model
Aesthetic value				
1282 ancient and veteran trees (combination of Woodland Trust and Estate tree inventory)	1282 ancient and veteran trees, of which 504 have a diameter over 1.5 metres and 3 exceed 3 metre diameter.	Structural value £4.74 million for the 1070 trees that had full data.	Medium	Estimate from the iTree-Eco model, an established model, but still subjective. Estimate includes crown health; dead and dying trees have a reduced valuation.
Blenheim Park	80% of respondents mentioned beautiful views as being one of the benefits of visiting the Park		High	Survey results backed by strong qualitative evidence (see Annex 2)
All estate habitats, including 953 ha of semi-natural habitats, rivers and lakes (hedgerows not included in the scores). 1353 ha of the farmland in the west of the Estate is in the Cotswolds Area of Outstanding Natural Beauty.	Score per ha: Estate 3.81 Park 6.34 Oxfordshire 3.51		Low	Indicative score based on habitat type.

Assets	Quantity	Monetary value	Confidence	Comments
Education				
Six woodlands used for Forest Schools and other outdoor education activities. Dedicated forest school site in the Park.	Regular weekly forest education activities for seven local schools and charities is estimated to deliver over 20,000 student-hours of education per year, valued highly by teachers and children. There are also many other activities.		High	Qualitative assessment based on interviews with three forest school leaders .
Blenheim Park	Opportunities for learning about nature were identified as a benefit by 24% of the respondents to the survey of Park users		High	Opportunities to improve this service by providing additional signage and information in the Park.
All estate habitats (hedgerows not included in the scores)	Score per ha: Estate 3.16 Park 5.47 Oxfordshire 2.61		Low	Indicative score based on habitat type. Semi-natural habitats are assumed to offer more opportunities for learning about nature.
Interaction with nature				
Blenheim Park	Opportunities for interacting with nature were identified as a benefit by 59% of the respondents to the survey of Park users		High	Survey results backed by strong qualitative evidence (see Annex 2)
All estate habitats (hedgerows not included in the scores)	Score per ha: Estate 2.56 Park 4.89 Oxfordshire 2.24		Low	Indicative score based on habitat type. Semi-natural habitats are assumed to offer more opportunities for interacting with nature.
Sense of place				
Blenheim Park World Heritage Site and Historic Park and Garden.	41% of the respondents to the survey of Park users listed sense of place as a benefit, and 59% listed history and culture.		High	Survey results backed by strong qualitative evidence (see Annex 2)

Assets	Quantity	Monetary value	Confidence	Comments
All estate habitats (hedgerows not included in the scores)	Score per ha: Estate 3.75 Park 6.66 Oxfordshire 3.25			
Biodiversity All estate habitats (hedgerows not included in the scores). Includes 5 SSSIs (256 ha of which 197 ha are in favourable condition and 52 ha are declining), 8 local wildlife sites (250 ha), one proposed local wildlife site, and 20 ancient woodlands (310 ha).	Score per ha: Estate 3.16 Park 5.06 Oxfordshire 2.80 Species observed include 14 species of bats, badgers, otter, marsh tit, skylark, song thrush, spotted flycatcher, barn owl, great crested newts, grass snake, adder, slow-worm and common lizard.		Low	Indicative score based on habitat type, roughly corresponding to the distinctiveness scores in the Defra Biodiversity Metric 2.0 but without data on habitat condition. New survey is ongoing in High Park and results can be incorporated later.
Habitat networks 9% of the Estate forms part of the Core zone and 58% is part of the Recovery zone of Oxfordshire's Nature Recovery Networks	451 ha of Core Zone NRN and 2800 ha or Recovery Zone.			Blenheim is in a key position within the new Nature Recovery Networks for Oxfordshire, which will add value to habitat restoration initiatives.

2 Introduction

This report is an initial assessment of the natural capital of the Blenheim Estate, carried out by the Environmental Change Institute at the University of Oxford, between September 2019 and September 2020. It includes:

- An introduction to the concept of natural capital, and description of the 18 ecosystem services assessed (Section 3).
- An inventory and maps of the extent and condition of the Estate's natural capital assets, including habitats, species, natural features, landscape quality, cultural assets, soil, water and productive land (Section 3).
- Assessment of the 18 ecosystem services delivered by the natural capital assets (Section 4), including a mix of qualitative, quantitative and monetary measures, and maps showing high value areas for different ecosystem services. This includes the results and analysis of a public participatory mapping exercise, identifying the cultural benefits delivered by the estate's natural capital for local people and visitors (full details in Annex 2).
- An overall summary and discussion of the ecosystem services and benefits provided by the estate, identifying strengths, threats and opportunities for improving the value of the estate's natural capital (Section 5).
- A methodology for carrying out annual updates to the figures and recommendations for future extensions to the methodology (Section 6).

It is hoped that these results can be used for:

- Engaging the public, visitors and local communities;
- Building the brand, demonstrating a commitment to sustainability and showing leadership nationally and internationally;
- Demonstrating the wider value of the estate (beyond conventional economic value) to investors, local authorities and regulators, and building a 'social license to operate';
- Identifying opportunities to increase natural capital value through well-targeted enhancements;
- Making the business case for investing in natural capital on the estate; and
- Providing metrics to measure year-on-year performance.

3 What is natural capital?

Natural capital is defined as the elements of the natural environment (soil, rocks, water and all living things) that deliver goods and services with benefits for people¹. These include provision of food, water and timber, protection from threats such as flooding and erosion, and cultural benefits such as attractive views and green spaces for recreation. These are called ‘ecosystem services’ (Figure 1, Table 1).

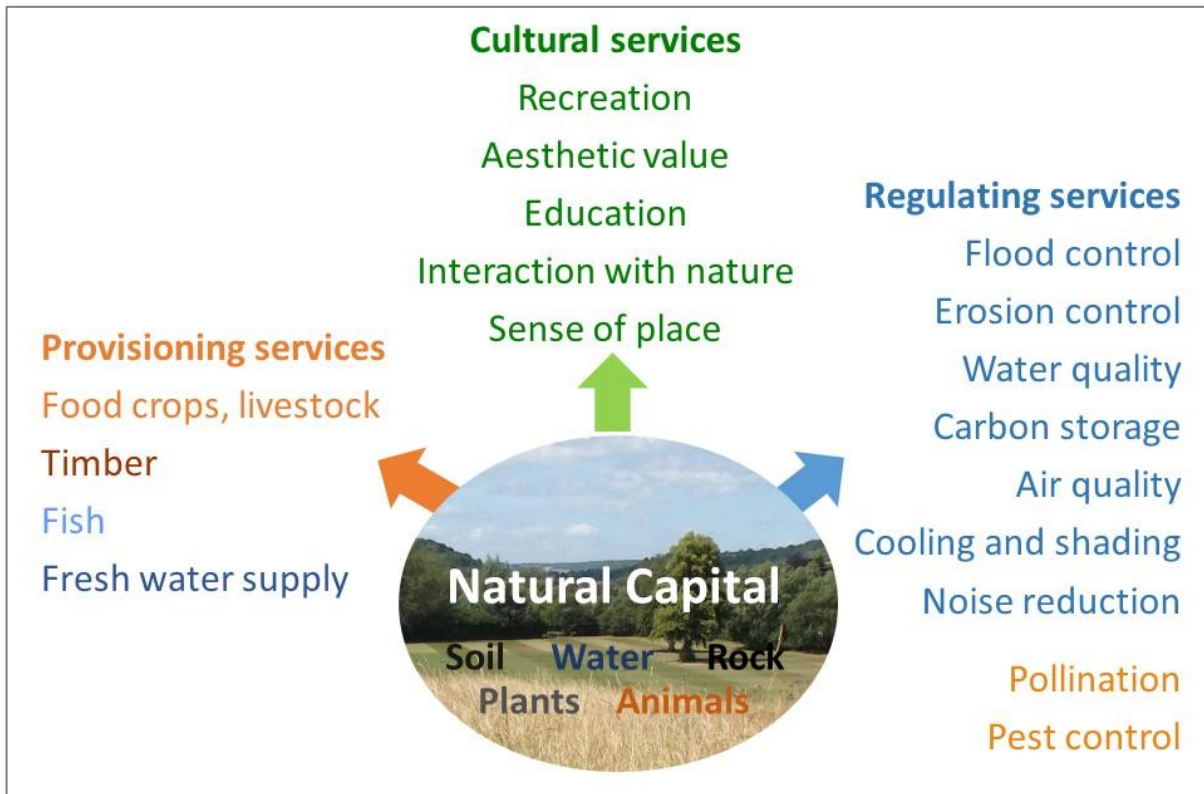


Figure 1: Natural capital provides a wide range of services needed by people, called ‘ecosystem services’

Many businesses and governments now recognise the need to maintain healthy stocks of natural capital in order to continue delivering these essential services sustainably into the future. For example, the UK Government’s 25 Year Environment Plan aims to “**set gold standards in protecting and growing natural capital – leading the world in using this approach as a tool in decision-making**”².

The National Planning Policy Framework also states that planning policies should “**plan for the enhancement of natural capital at a catchment or landscape scale across local authority boundaries**”³.

Major reports by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)⁴ and WWF⁵ have emphasised the urgency of reversing the steep decline in biodiversity and natural capital, to safeguard human wellbeing and protect species at risk of extinction. In the business world, there is increasing awareness of the many ways in which businesses depend on natural capital, and also the threats to natural capital from over-exploitation of resources, climate change, land-use change and biodiversity loss. Over 300 organisations from across the globe are now members of the Natural Capital Coalition, including the Crown Estate, the Forestry Commission, Thames Water, the Food and Drink Federation, Dow, Coca-Cola, M&S, KPMG and Unilever.¹ Members of the coalition are working to assess their natural capital assets and impacts, and find ways to make their operations and supply chains sustainable in the long term.

¹ <https://naturalcapitalcoalition.org/who/coalition-organizations/>

Table 1. Ecosystem services

Provisioning	Food production	Arable crops, horticulture, livestock, orchards, allotments, urban food and/or wild food (e.g. gathering berries or mushrooms).
	Wood production	Timber, wood production for paper, woody biofuel crops, coppice wood or wood waste used for biofuel.
	Fish production	Commercial or recreational fishing (recreational fishing is also a cultural service, but the habitat conditions match those for fish production).
	Water supply	Impact of soil and vegetation on rainwater runoff and infiltration, and thus on groundwater recharge or surface water flow.
Regulating	Flood regulation	Reduction of surface runoff, peak flow, flood extent and flood depth through canopy interception, evapotranspiration, soil infiltration and physical slowing of water flow.
	Erosion protection	The ability of vegetation to stabilise soil against erosion and mass wastage by protecting the soil from the erosive power of rainfall and overland flow, trapping sediment, and binding soil particles together with roots.
	Water quality regulation	Direct uptake of pollutants by terrestrial or aquatic vegetation; interception of overland flow and trapping / filtration of pollutants and sediment by vegetation before it reaches watercourses; breakdown of pollutants into harmless forms e.g. by bacteria.
	Carbon storage	Carbon stored in vegetation and soil.
	Air quality regulation	Removal of air pollutants by deposition, absorption and/or breakdown by vegetation.
	Cooling and shading	Shade, shelter and cooling effect of vegetation and water, especially urban trees close to buildings, green roofs and green walls, which can reduce heating and cooling costs, or trees in urban parks which can provide shade on hot days.
	Noise reduction	Attenuation of noise by vegetation: only relevant where trees or shrubs form a barrier between a busy road or other noise source and a place used by people.
	Pollination	Pollination of crops (and wild plants, supporting other ES) by wild insects (mainly bees and hoverflies). Excludes pollination by managed honeybees.
Cultural	Pest control	Predation of crop or tree pests by invertebrates (e.g. beetles, spiders, wasps), birds and bats.
	Recreation and leisure	Provision of green and blue spaces that can be used for any leisure activity, e.g. walking, cycling, running, picnicking, camping, boating, playing or just relaxing.
	Aesthetic value	Provision of attractive views of nature and beautiful surroundings.
	Education and knowledge	Opportunities for formal education (e.g. school trips), scientific research, local knowledge and informal learning (e.g. from information boards or experiences).
	Interaction with nature	Provision of opportunities for formal or informal nature-related activities, e.g. bird watching, botany, random encounters with wildlife, or feeling 'connected to nature'.
Cultural	Sense of place	The aspects of a place that make it special and distinctive – this could include locally characteristic species, habitats, landscapes or features; places related to historic and cultural events, or places important to people for spiritual or emotional reasons.

4 Inventory of the natural capital assets of the Blenheim Estate

Natural capital assets include the habitats, species, soil, water and productive land at the Estate, and the historic features, cultural heritage and landscape. Here we report the assets for the whole 4,858 ha (12,000 acre) estate, but we also provide a separate breakdown specifically for Blenheim Park (975 ha), as this is a distinct area with different characteristics to the rest of the Estate. This section presents an asset inventory covering habitats and land use, species, soil and water, including both asset extent and condition. Section 4 describes the ecosystem services that flow from those assets.

4.1 Habitats and land use

We based our analysis on a detailed map of the different habitats and types of land use in Oxfordshire, which was compiled using an automated process developed by the University of Oxford for mapping natural capital⁶. This combines the generic datasets listed below in a systematic way, starting with OS Mastermap and then progressively incorporating the TVERC habitat map, CROME, designations and green space data.

- Ordnance Survey MasterMap⁷ (12/07/2018 version). This is a very detailed base map showing every house, garden, field and road, as well as some information on the natural environment (e.g. presence of coniferous or broadleaved trees, scrub, marsh or rough grass). © Crown Copyright and database right 2020 Ordnance Survey 100025252.
- Thames Valley Environmental Records Centre (TVERC) Phase 1 Habitat and Land Use survey⁸ (December 2019 version). Copyright to TVERC and its partners. This maps semi-natural habitats and S41 Habitats of Principal Importance (previously called UKBAP priority habitats), such as the different types of semi-natural grassland (acid, neutral, calcareous) that have distinctive plant species. It is based mainly on aerial photos but uses ground survey data where available, e.g. for nature reserves. It is updated every 6 months but not all polygons are updated each time.
- CROME land use data from the Rural Payments Agency⁹, which provides more up to date and detailed information on the land use for farmland, including crop type (2019 version, containing data for 2018). © Rural Payments Agency. Available under an Open Government License.
- Ordnance Survey GreenSpace data (OS Open Greenspace, freely available, and OS Mastermap Greenspace, © Crown Copyright and database right 2020 Ordnance Survey 100025252), showing different types of urban green space including allotments, playing fields, churchyards and cemeteries.
- Nature and cultural designations, including AONBs, Local and National Nature Reserves, Sites of Special Scientific Interest (SSSIs), Local Wildlife Sites and Local Geological Sites, Ancient Woodlands and Scheduled Ancient Monuments. These are freely available datasets downloaded from data.gov.uk under an Open Government License, except for the Local Wildlife Sites which are licensed from TVERC.

We made a number of specific corrections to ground-truth the map of the Estate, such as adding the kitchen gardens, playground, hedge maze, fountains and flower beds in the Pleasure Gardens and Palace Gardens, and correcting some grassland areas in the Park which were mapped incorrectly as arable crops in CROME. The habitat map is shown in Figure 2, with a close up of the Park in Figure 3.

Blenheim Park is an internationally famous landscape centred on the Palace and lake, designated as a World Heritage Site (WHS). It contains several distinct zones.

- The Palace, lake and gardens. This area includes formal gardens with flower beds and fountains behind the Palace, the larger informal gardens south of the Palace consisting of grassland, shrubs and trees, and the Pleasure Gardens containing a hedge maze, butterfly house and play areas.
- The area immediately north of the lake, including the Monument, which is parkland with scattered trees and is a proposed Local Wildlife Site.
- Parkland with scattered trees, including many ancient oaks, in the south-east part of the Park.
- Woodland in the south-west of the Park, designated as a Site of Special Scientific Interest (in the area known as High Park). This was formerly wood pasture, but although there are still some areas of

grassland with scattered trees it now consists mainly of ancient semi-natural closed canopy woodland that has grown around the numerous ancient and veteran oak trees, as well as blocks of broadleaved, coniferous and mixed plantations that are managed for timber and biomass.¹⁰

- The fields in the northern half of the Park. These were arable cropland until 2010, when the area was reverted to improved grassland and used to graze sheep. Small patches and strips of woodland are dotted around this area, and it contains sections of Grim's Ditch, and other archaeological features.

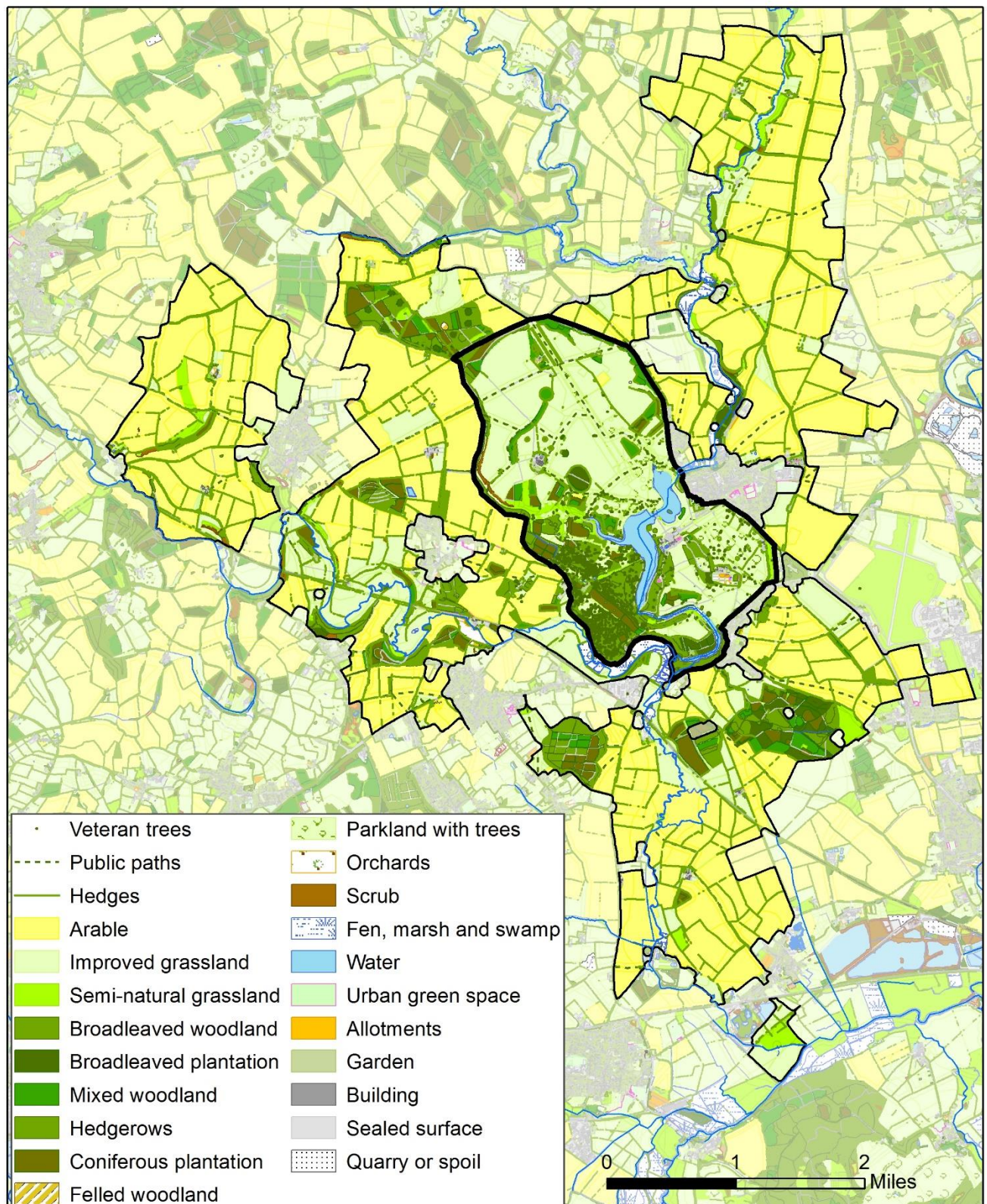
In contrast, the wider estate beyond the Park is far more typical of Oxfordshire as a whole, being mainly intensively farmed arable fields with smaller areas of woodland and grassland.

Table 2 reports the extent (area) of different types of habitat and land use for the Park, the rest of the Estate and the whole Estate. Line and point features (hedges, streams, paths and ancient trees) are shown separately in Table 4.

Table 2. Habitat extent inventory for Blenheim Estate (ha)

Habitat	Park (ha)	Rest of Estate (ha)	Whole Estate (ha)
Arable and horticulture	4	2,685	2,689
Improved grassland	386	520	906
Total intensive farmland	390	3,205	3,595
Conifer plantation	47	113	160
Mixed woodland	50	47	96
Broadleaved plantation	19	51	70
Semi-natural broadleaved woodland	113	161	274
Unknown broadleaved woodland	65	64	129
Traditional orchards	1	6	7
Total woodland	294	442	736
Wood pasture and parkland and scattered trees	157	3	160
Scrub	4	15	19
Semi-natural grassland	30	118	147
Wetland	4	2	7
Total non-woodland semi-natural habitats	195	138	333
Total semi-natural habitats excluding water and conifer plantations	442	467	909
Rivers and streams	5	22	27
Lakes and ponds	48	2	50
Total semi-natural habitats incl. rivers, lakes and ponds	496	490	986
Canals, drains, fountains	1	2	3
Total water	54	26	80
Buildings	3	6	9
Road	10	5	15
Sealed surface, bridge, manmade path	9	9	18
Manmade unsealed surface (rail, quarry, track, felled woodland)	9	24	33
Total buildings and manmade surfaces	31	43	75
Gardens	5	10	15
Amenity grassland	4	17	22
Allotments	0	1	2
Sports and recreation (playing fields, playgrounds, golf etc)	0	1	1
Total gardens and urban green space	10	29	39
Total urban (buildings, manmade and green space)	41	73	114
Total	975	3,883	4,858

Habitats and land use on the Blenheim Estate



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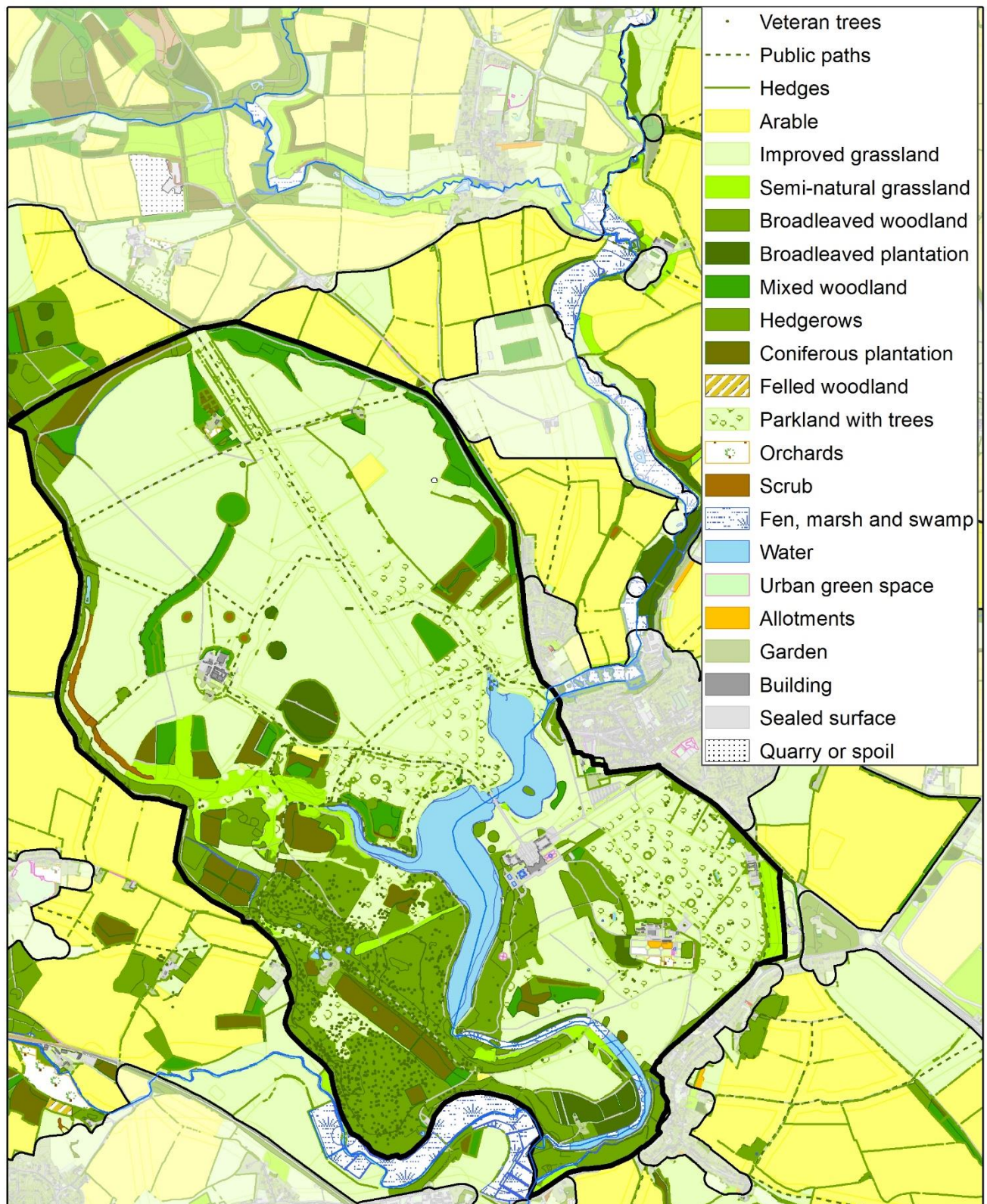
Ancient tree data is provided by the Woodland Trust.

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Figure 2. Habitat map of the Blenheim Estate

Habitats and land use in Blenheim Park



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Figure 3: Habitat map of Blenheim Park

The split of habitat types for the Estate is shown in Figure 4 and for the Park in Figure 5. The Park comprises a mix of semi-natural habitats and grassland, in contrast to Estate as a whole which is 73% intensive farmland (mainly arable) and 9% plantation woodland.

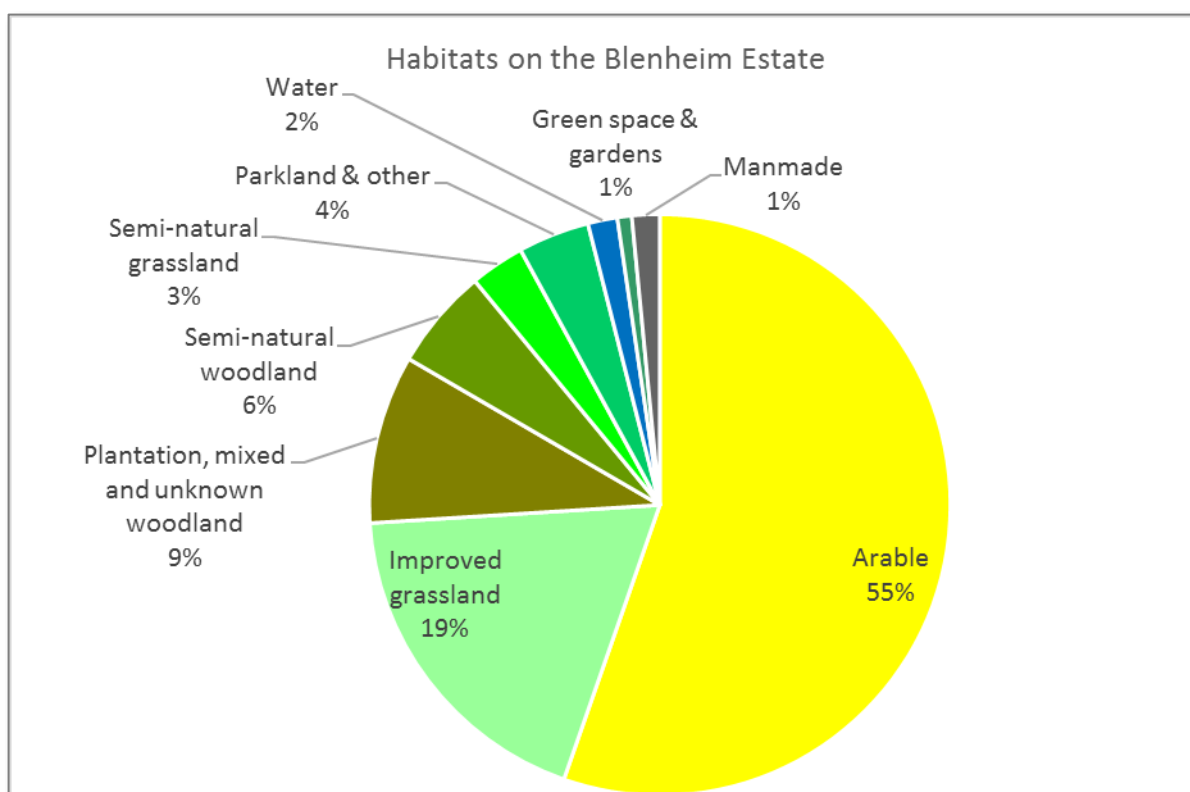


Figure 4. Habitat and land use mix on the Blenheim Estate (whole Estate including Park)

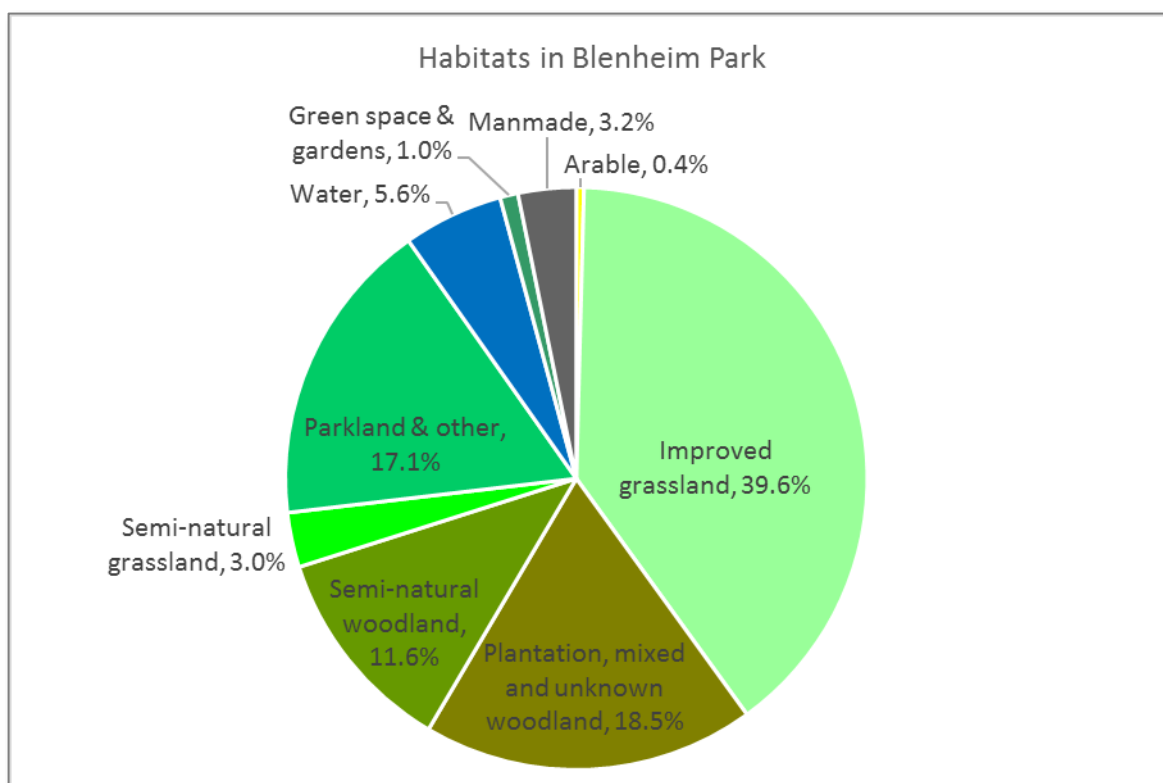


Figure 5. Habitats and land use mix in Blenheim Park

4.2 Individual trees and hedgerows

There are many ancient and veteran trees in the Park, both in the woodlands and in the wood pasture and parkland area. Those we have identified are shown as darker green dots on the habitat maps (Figure 2 and Figure 3). These have been mapped by combining the Estate's database of 1074 trees in the High Park woodlands in the south-west of the Park with the Woodland Trust's Ancient Tree Inventory¹¹, which includes 480 trees in the Park and two elsewhere on the Estate. The Woodland Trust inventory has been mapped through citizen science, so it may not provide a complete record of all the trees on the Estate – especially outside the Park where only two trees have been recorded so far. However it is clear that the 482 trees at Blenheim form a very high proportion of the 2251 total ancient and veteran trees recorded by the Woodland Trust for Oxfordshire (February 2019 version).

To merge the two datasets we used only the Estate database for the High Park area, excluding the 278 Woodland Trust trees in this area to avoid duplicates, but we included the 208 Woodland Trust trees elsewhere in the Park and Estate. This resulted in a total of 1282 veteran and ancient trees, mainly oaks (1008) but with some beech (149) and a few other species (Figure 6, Table 3).

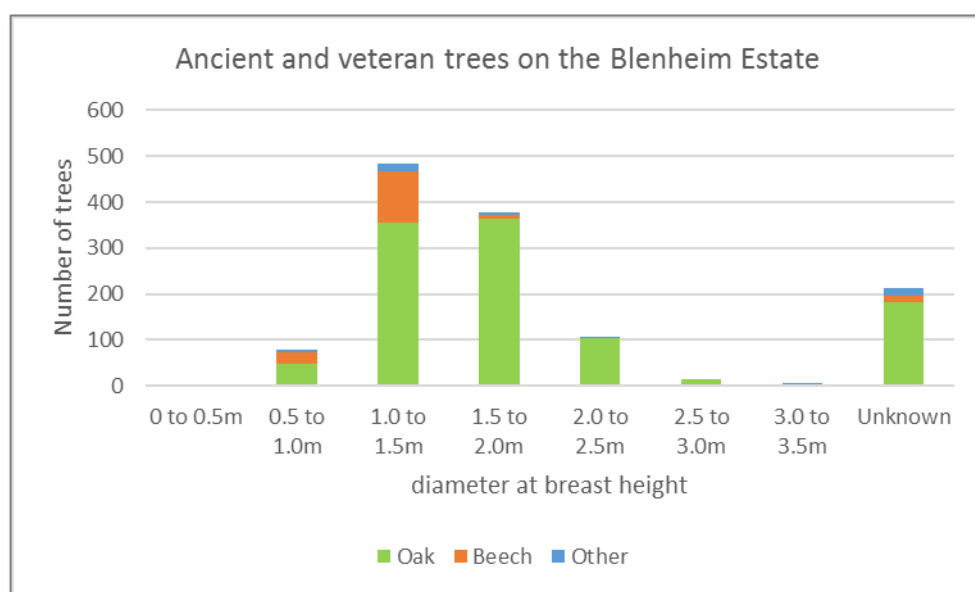


Figure 6. Ancient and veteran trees on the Blenheim Estate

Table 3. Ancient and veteran trees on the Blenheim Estate

Diameter at breast height	0 to 0.5m	0.5 to 1.0m	1.0 to 1.5m	1.5 to 2.0m	2.0 to 2.5m	2.5 to 3.0m	3.0 to 3.5m	Unknown	Total
Alder			1						1
Ash			2	1				1	4
Atlas cedar								1	1
Beech		25	112	9				16	162
Cedar			1	2	2				5
Cedar of Lebanon				2	2		1		5
Field maple	2	2	1						5
Lime		4	6	1				2	13
Oak		47	356	364	103	14	2	181	1067
Sycamore		1	2		1			1	5
Horse chestnut			3					8	11
Plane								1	1
Hawthorn		1							1
Hazel								1	1
Total	2	80	484	379	108	14	3	212	1282

Four of the ancient trees are listed on the global Monumental Trees citizen science website¹², two of which are oaks with a girth over 10 metres (diameter at breast height over three metres). Of the 1070 trees where size has been measured, 125 have a diameter over two metres. Analysis for the High Park Management Plan indicates that 70 of the largest trees could be over 700 years old and two could be over 900 years old.¹⁰

The inventory includes 65 fallen dead trees and 150 standing dead trees, which provide valuable wildlife habitat. Standing dead wood in particular is an extremely scarce habitat in the UK. The percentage of dead wood in the crown is recorded for the trees in the Estate inventory (Figure 7). The average for the 814 trees with condition data is 29%.

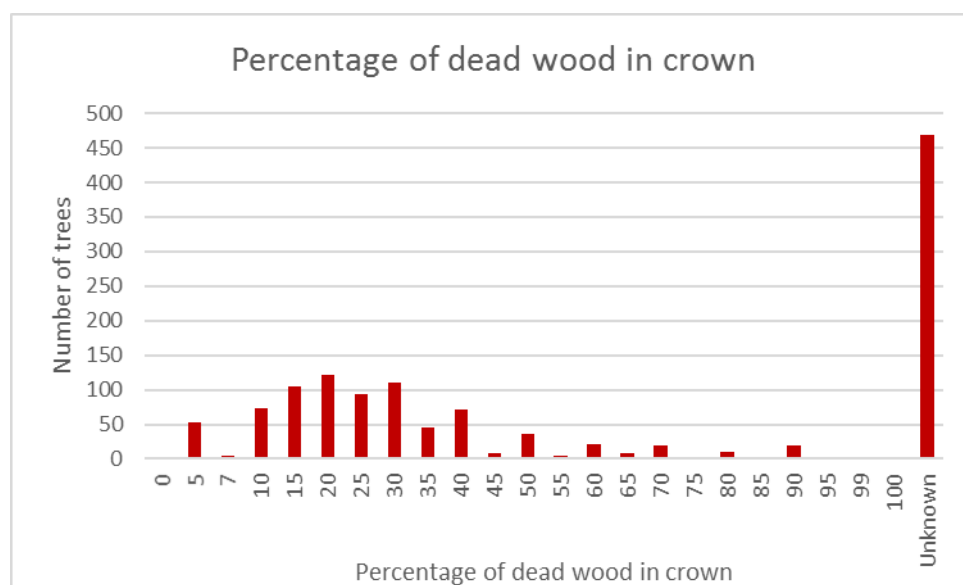


Figure 7. Percentage of dead wood in crown of ancient and veteran trees on the Blenheim Estate

We estimated the length of hedgerows using a database obtained under license from the Ordnance Survey to create the natural capital maps of Oxfordshire. OS mapped hedgerows using remote sensing data and LIDAR to identify places where vegetation above a certain height coincided with field boundaries. Clipping the hedgerow dataset to the Estate boundary shows that there are 135 km of hedgerows and 128 km of linear tree features (lines of trees or trees in hedgerows) along the field boundaries on the Estate. These are shown as green lines on the habitat maps.

Individual trees, hedgerows, paths, rivers (from OS Open Rivers¹³) and smaller streams and field drains (from the local layer in OS Open Zoomstack Waterlines¹⁴) are listed in Table 4.

Table 4. Line and point feature natural capital assets at Blenheim Estate and Park

Line and point features	Units	Estate	Park
Ancient trees (Woodland Trust data)	No.	482	480
Veteran trees (Estate inventory)		1074	1074
Combined ancient and veteran trees (duplicates removed)		1282	1282
Hedges and linear woodland features	km	262.15	34.46
Hedges	km	134.63	6.20
Lines of trees and woodland strips	km	127.51	28.26
Public rights of way	km	72.46	15.63
Sustrans off-road cycle routes	km	3.47	0.21
Rivers (including 2.1km length of lakes)	km	28.01	4.82
Small streams and field drains	km	11.66	0.05
All watercourses	km	39.67	4.87

4.3 Soil, geology and agricultural land class

Most of the northern and central parts of the Blenheim Estate overly limestone (the Great Oolite formation), but the south-eastern part overlies the Oxford Clay. Between the two is a thin band of interbedded sandstones and mudstones (Figure 8). The upper parts of the Glyme and Dorne valleys have also eroded down to the clay and mudstone layers. Superficial deposits of sand and gravel occur mainly along the river valleys, with some more extensive deposits in the southern part of the Estate.

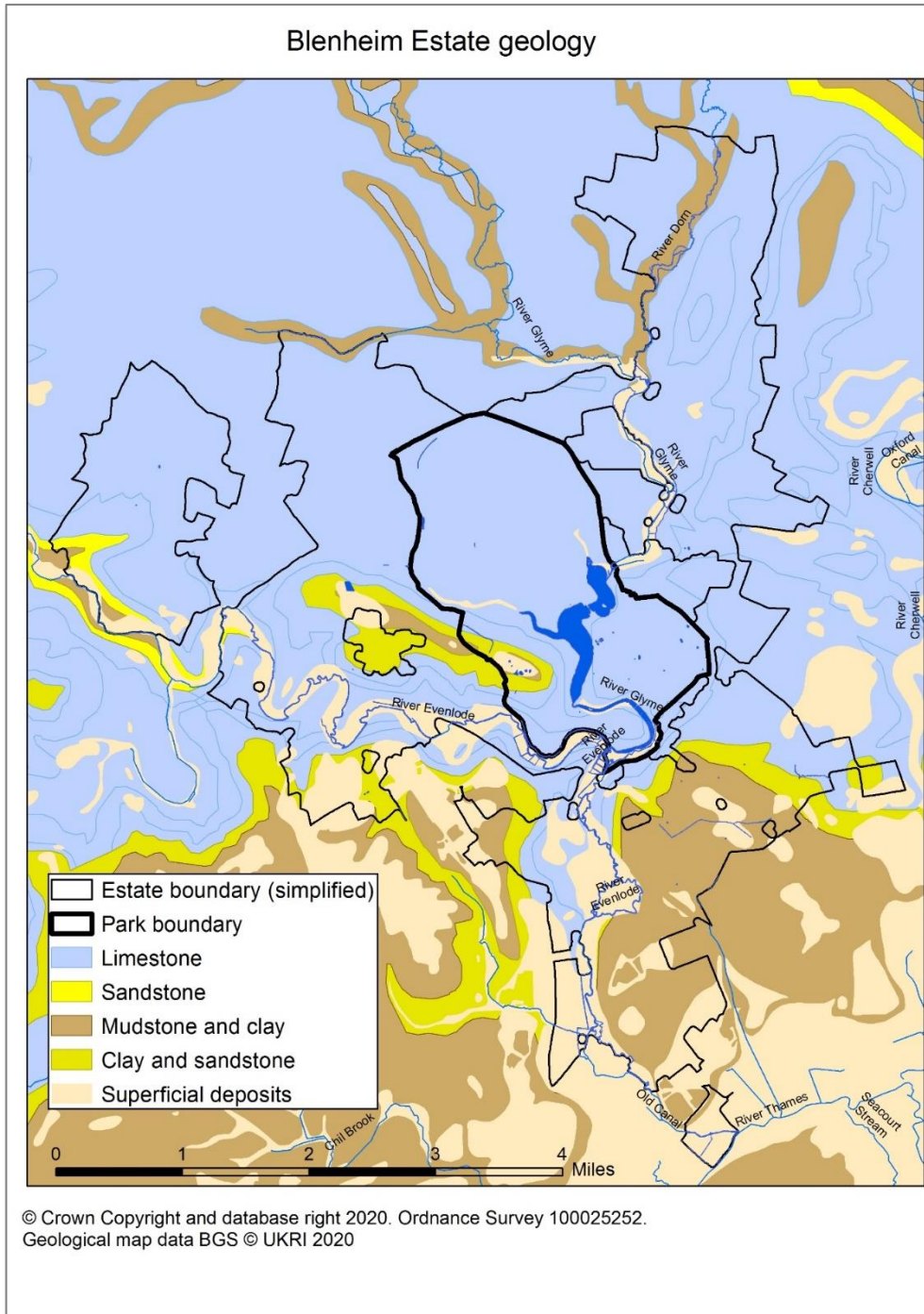


Figure 8. Bedrock geology

Soils on the estate reflect the underlying parent material (Figure 8). The northern and central limestone areas give rise to freely draining lime rich loamy soils, shallow and stoney in places, while those in the southern part, overlying the Oxford Clay and in the River Evenlode valley, are slowly permeable, seasonally wet, acid loamy and clayey soils. In High Wood, in the south-east part of the Park, an outlying patch of clay with superficial

clayey gravel deposits gives rise to poor soil and damp conditions. As this area is less suitable for cultivation, this has led the preservation of the semi-natural woodland including a small patch of ancient woodland.¹⁵

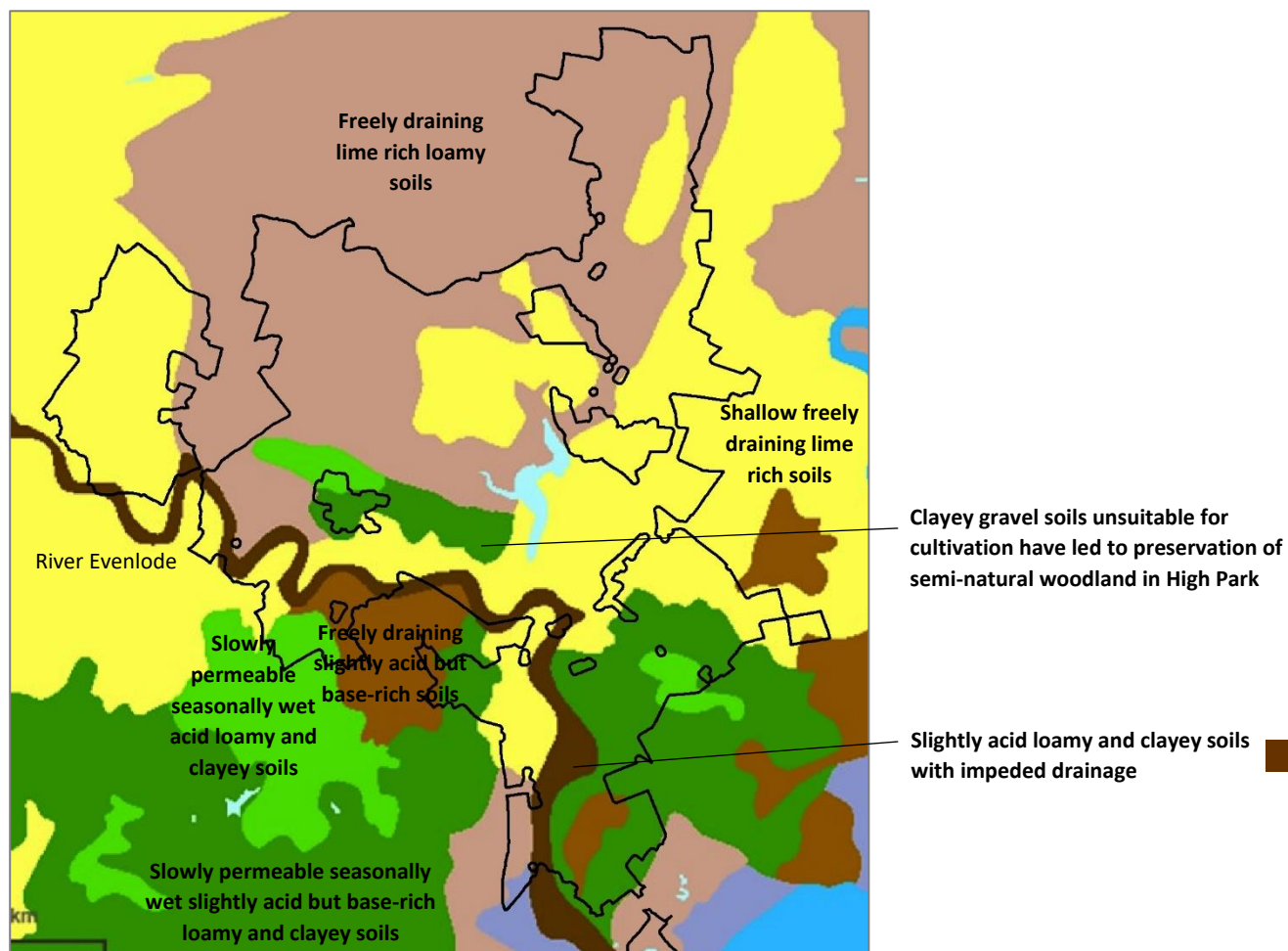


Figure 9. Soil types. Screenshot of Landis Soilsclapes Viewer <http://www.landis.org.uk/soilsclapes/>. Soils Data © Cranfield University (NSRI) and for the Controller of HMSO 2020.

The soil types in turn influence the soil productivity for agriculture. The lime-rich soils are well drained but fairly shallow and stony, with average fertility, while the clay soils are highly fertile but generally poorly drained. Most of the Blenheim Estate is therefore classed as Grade 3 (average) agricultural land use class, with lower quality Grade 4 land along the river valleys where the ground is poorly drained and sloping, and a small patch of Grade 2 land in the southernmost part (Figure 10). All the Grade 2 and most (80%) of the Grade 3 land is used for arable crops, while the Grade 4 land is split between arable and grazing (Table 5, Figure 11).

Table 5. Farmland on the Blenheim Estate by Agricultural Land Class. Grade 1 is the highest quality; Grade 5 the lowest. Grades take into account soil type, slope, stoniness, drainage and aspect.

Farmland	ha	% of farmland	
Arable	2,689	75%	% of arable
Grade 2	51	1%	1.9%
Grade 3	2,400	67%	89.2%
Grade 4	237	7%	8.8%
Unknown grade	1	0%	0.0%
Improved grass	906	25%	% of improved grass
Grade 2	0	0%	0.0%
Grade 3	726	20%	80.1%
Grade 4	180	5%	19.9%
Total farmland	3,595		

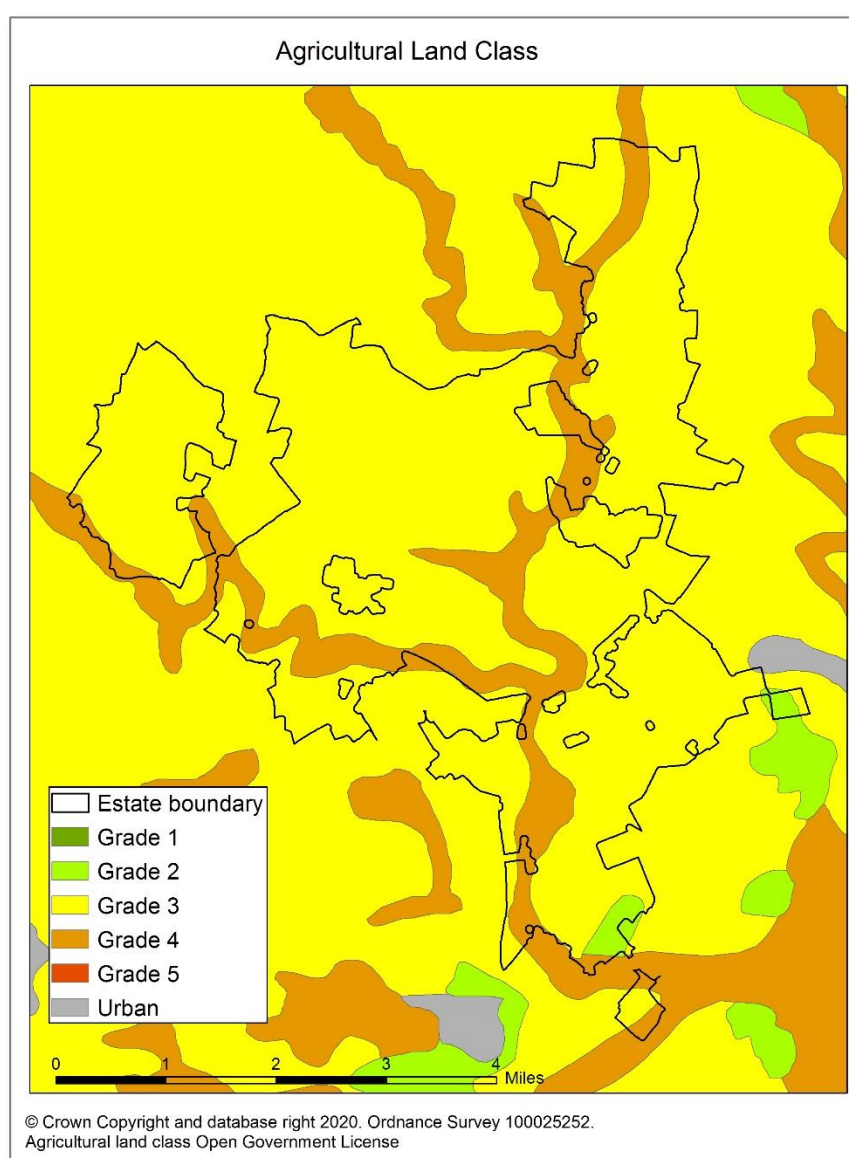


Figure 10. Agricultural land use class at Blenheim

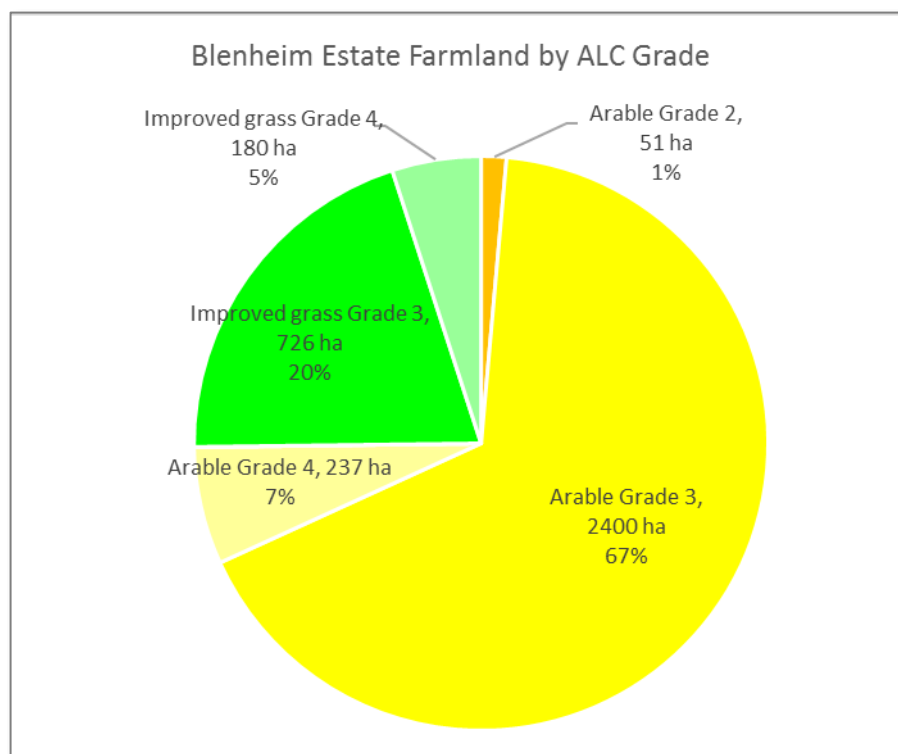


Figure 11. Split of farmland on the Estate by ALC grade

4.4 Water

The Blenheim Lake covers 48.5 ha and the Estate also contains around 1 ha of smaller lakes and ponds, mainly in the southern part of the Park and Bladon Heath. There is a total 39 km of watercourses, including 28 km of rivers and 11 km of smaller streams, drains and ditches. Three rivers flow through the Estate, starting with the Dorne in the north-east, which flows south to join the Glyme near Wootton. The Glyme flows into the Blenheim lakes and then south until it meets the Evenlode on the southern edge of the Park. The Evenlode then continues southwards to eventually flow into the Thames at the southern tip of the Estate.

Data on water quality is available via the Environment Agency Catchment Data Explorer, which records monitoring for the Water Framework Directive (WFD). The last full WFD assessment was Cycle 2, released in 2016 and based on data gathered from 2013 to 2016. Another assessment was due in May 2020 but has not yet been released (checked 14 Sept 2020). The overall WFD ecological and chemical status of the Glyme and Dorn rivers in the sub-catchments covering the Blenheim Estate was poor in Cycle 2, and the overall status of the Evenlode to the south of the Park was bad (Figure 13). The Blenheim Lakes and the sections of the Evenlode to the west of the Park achieved moderate status, as did the two Cherwell sub-catchments and the Thames catchment to the east of the Estate. Overall, 70% (59 ha) of the area of waterbodies on the Estate was moderate status (mainly the Blenheim Lakes), 17% (14 ha) was poor and 13% (11 ha) was bad (Figure 12).

The overall status is determined by the lowest rating for all components of the assessment. In WFD Cycle 2, the chemical status of all the rivers was good but the ecological status was not, mainly due to high phosphate levels and poor species abundance and diversity of aquatic plants and fish, which tended to deteriorate from 2013 to 2016 (Table 6). The most commonly cited 'reasons for not achieving good status' were sewage discharge and poor nutrient management, followed by physical barriers (e.g. weirs or dams), land drainage and invasive species (signal crayfish). However the Evenlode upstream of the Glyme confluence was rated 'good' for aquatic invertebrates, and all the rivers were rated good for the naturalness of the channel shape (morphology) and flow patterns (hydrology).

A survey by BSG Ecology in 2014-2015¹⁶ showed that the lakes were hyper-eutrophic and suffering from increasingly frequent algal blooms, sometimes including toxic blue-green algae that is harmful to people, dogs

and wildlife. This was attributed to high phosphate levels in the River Glyme, which increase four-fold downstream of Woodstock Sewage Treatment Plant, and accumulated phosphate in the lake sediment. In addition, the lake has been filling with sediment and invasive pondweed has been spreading. The lake was found to be in 'unfavourable declining' status when assessed according to the criteria for monitoring SSSIs. Although it was not assessed in WFD terms, this suggests that it may now be in Poor status rather than Moderate. Preparations are currently being made to dredge the lake in order to try to address these issues.

Some more recent metrics are available in the Environment Agency water quality 'archive' which is updated more frequently than the WFD status. These include specific water quality measurements upstream and downstream of the Park (e.g. dissolved oxygen levels), but no overall quality assessment, no ecological assessment and no data for the lakes and rivers within the Park. In future, it would be useful to integrate additional local water quality measurements into updates of this Natural Capital Assessment, including further targeted surveys by consultants as well as citizen science initiatives such as the Water Blitz. This could be particularly useful to establish the condition of the isolated ponds on the Estate, which are currently mapped as being the same quality as the main river in the catchment.

Figure 12. Area of waterbodies on the Blenheim Estate (ha) by Water Framework Directive overall ecological and chemical status.

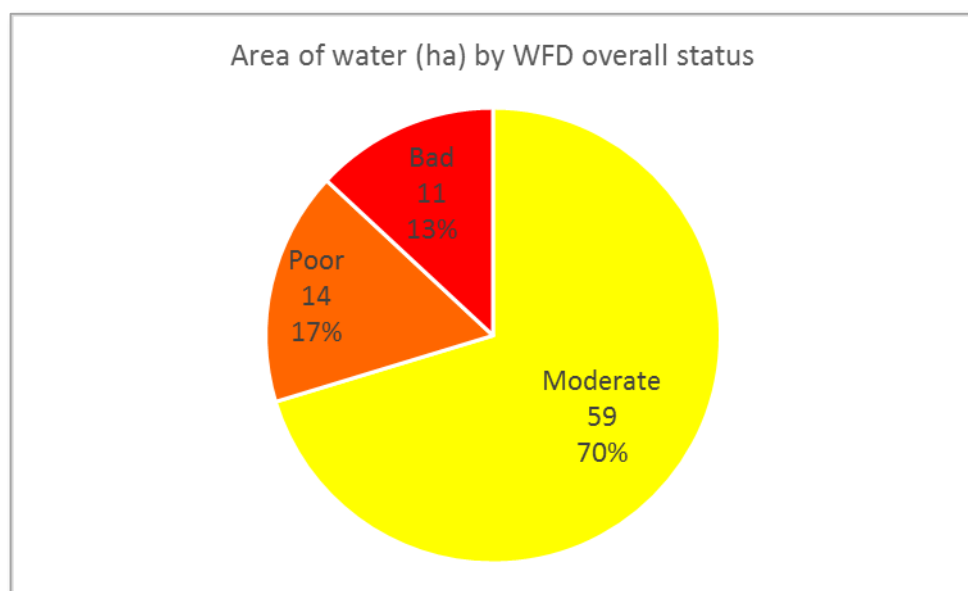


Table 6. Trends in Water Framework Directive status for selected indicators over Cycle 2 (2013 to 2016)

WFD Cycle 2	Hydrological Regime	Morphology	Fish	Invertebrates	Macrophytes & Phytobenthos	Biological elements	Phosphate	Ecological	Chemical	Overall
Glyme (Enstone to Dorn)										
2013	High	Supports Good			Moderate	Moderate		Moderate	Good	Moderate
2014	High	Supports Good	Moderate	High	Moderate	Moderate		Moderate	Good	Moderate
2015	High	Supports Good	Moderate	High	Moderate	Moderate	High	Moderate	Good	Moderate
2016	High	Supports Good	Moderate	High	Poor	Poor	High	Poor	Good	Poor
Dorn (Source to Glyme)										
2013	Supports Good	Supports Good	Poor			Poor		Poor	Good	Poor
2014	Supports Good	Supports Good	Poor	Moderate		Poor	Moderate	Poor	Good	Poor
2015	Supports Good	Supports Good	Poor	Moderate	Poor	Poor	Moderate	Poor	Good	Poor
2016	Supports Good	Supports Good	Poor	Moderate	Poor	Poor	Moderate	Poor	Good	Poor
Glyme (Dorn confluence to Evenlode)										
2013	Supports Good	Supports Good			Moderate	Moderate		Moderate	Good	Moderate
2014	Supports Good	Supports Good		Good	Moderate	Moderate	Moderate	Moderate	Good	Moderate
2015	Supports Good	Supports Good	Poor	Good	Moderate	Poor	Moderate	Poor	Good	Poor
2016	Supports Good	Supports Good	Poor	Good	Poor	Poor	Moderate	Poor	Good	Poor
Blenheim Lakes										
2015								Moderate	Good	Moderate
2016	Supports Good							Moderate	Good	Moderate
Evenlode (Bledington to Glyme confluence)										
2013	Supports Good	Supports Good		High		High		Moderate	Good	Moderate
2014	Supports Good	Supports Good	Moderate	High		Moderate		Moderate	Good	Moderate
2015	Supports Good	Supports Good	Moderate	High	Moderate	Moderate	Poor	Moderate	Good	Moderate
2016	Supports Good	Supports Good	Moderate	Good	Moderate	Moderate	Poor	Moderate	Good	Moderate
Evenlode (Glyme to Thames)										
2013	Supports Good	Supports Good			Good	Good	Poor	Moderate	Good	Moderate
2014	Supports Good	Supports Good		High	Good	Good	Poor	Moderate	Good	Moderate
2015	Supports Good	Supports Good	Bad	High		Bad	Poor	Bad	Good	Bad
2016	Supports Good	Supports Good	Bad	High		Bad	Poor	Bad	Good	Bad
Thames (Evenlode to Thame)										
2013	Supports Good	Supports Good	Moderate			Moderate	Moderate	Moderate	Good	Moderate
2014	Supports Good	Supports Good	Moderate	Moderate		Moderate	Moderate	Moderate	Good	Moderate
2015	Supports Good	Supports Good	Moderate	Moderate		Moderate	Moderate	Moderate	Fail	Moderate
2016	Supports Good	Supports Good	Good	Moderate		Moderate	Moderate	Moderate	Fail	Moderate

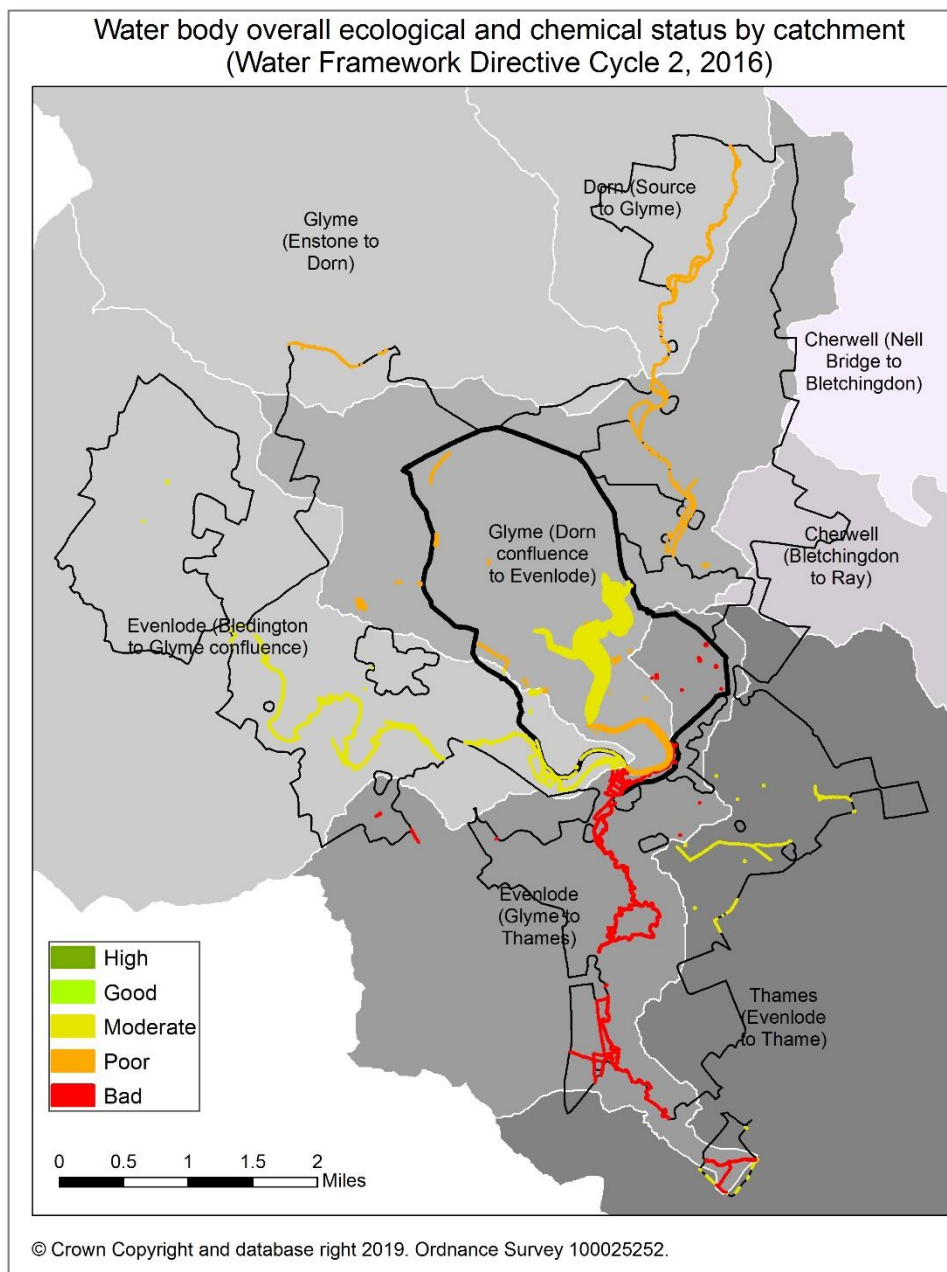


Figure 13. Overall ecological and chemical status of water bodies by catchment, from 2016 Water Framework Directive data. All waterbodies in a catchment are assumed to have the same water quality as the main watercourse, though isolated ponds may well have a different quality. Lower catchments are shown in darker shades of grey.

Similarly, data from the WFD (Cycle 2, 2013-16) is also available for groundwater bodies (aquifers). The Blenheim Estate overlies five different groundwater bodies, of which the two northern ones, covering 75% of the Estate, were rated poor for chemical status (Figure 14) and the other three, covering 15%, were rated good (the remaining 10% of the Estate does not overlie any groundwater bodies). The reasons for not achieving good status were due to poor nutrient management and sewage treatment. All five aquifers were rated good for quantitative status, indicating that they were not over-abstracted.

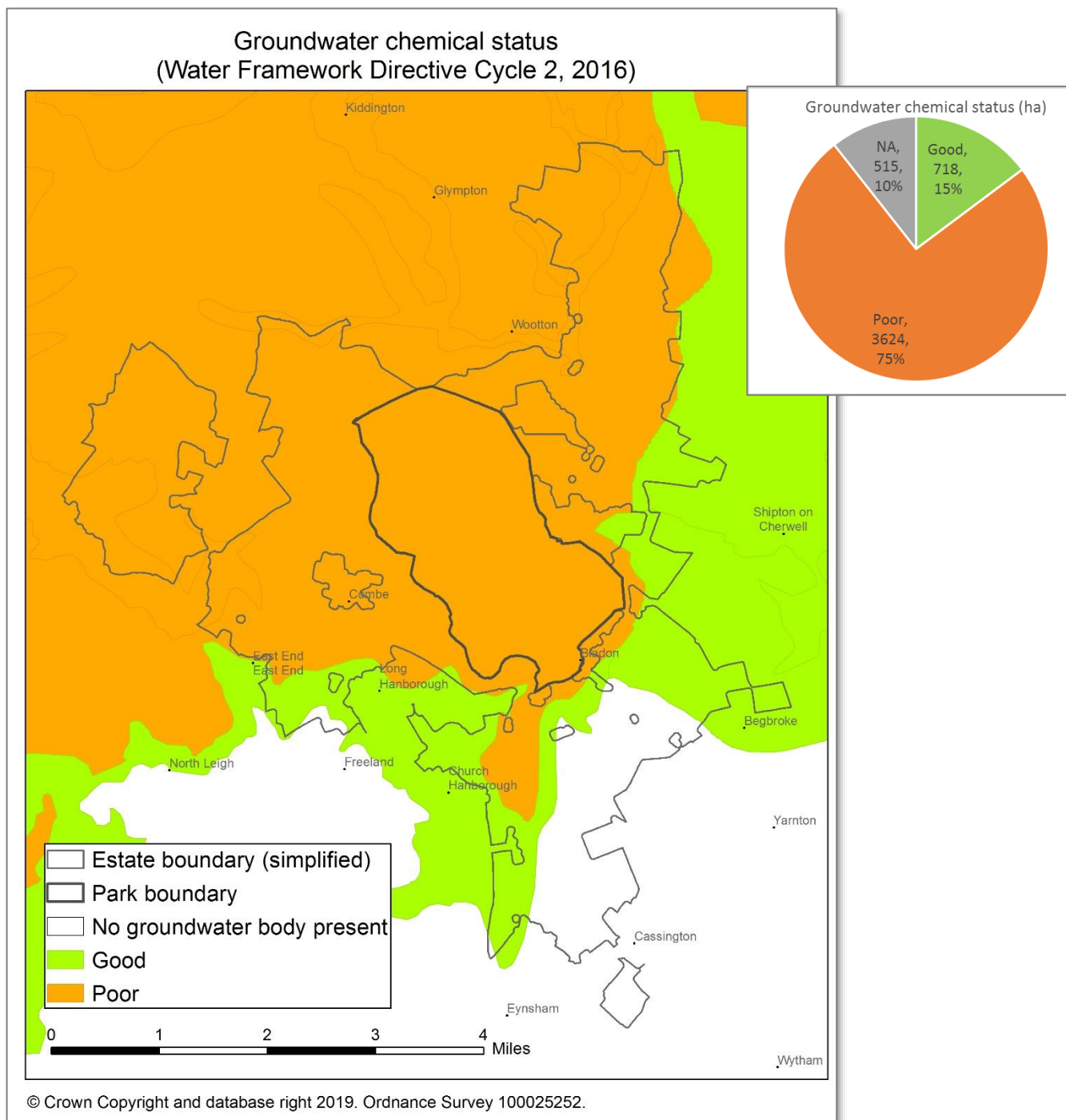


Figure 14. Groundwater chemical status according to the Water Framework Directive Cycle 2 (2013-2016)

4.5 Biodiversity

4.5.1 Semi-natural habitat inventory

The Estate includes 986 ha of semi-natural habitats, defined here as including both semi-natural and plantation broadleaved woodland and mixed woodland but not conifer plantations, and rivers, streams, lakes and ponds but not canals and drains (Table 7). The main type of semi-natural habitat present is semi-natural broadleaved woodland, but there are also large areas of wood pasture and parkland with scattered trees, and some semi-natural neutral and calcareous grassland (Figure 15).

Over half of the semi-natural habitats are found within the Park, but the wider estate contains many blocks of ancient woodland, small pockets of semi-natural grassland and several important wildlife sites.

Table 7. Semi-natural habitats on the Blenheim Estate and Park

Habitat	Estate (ha)	Park (ha)
Mixed woodland	96.4	49.6
Broadleaved plantation	70.2	19.0
Semi-natural broadleaved woodland	273.5	113.1
Unknown broadleaved woodland	129.2	64.7
Traditional orchards	7.2	1.2
Total woodland excluding conifer plantations	576.6	247.5
Wood pasture and parkland and scattered trees	160.4	157.2
Scrub	18.6	3.8
Acid grassland	2.0	2.0
Neutral grassland - unimproved	10.8	-
Neutral grassland - semi-improved	22.2	6.2
Neutral grassland - unknown	7.7	5.7
Calcareous grassland	25.9	13.0
Floodplain grazing marsh	37.2	0.1
Semi-natural grassland - unknown	41.0	2.6
Reedbed	4.2	4.2
Lowland fens	2.1	-
Other wetland	0.2	-
Total non-woodland semi-natural habitats	332.5	194.9
Rivers and streams	26.6	5.0
Lakes and ponds	49.9	48.3
Total semi-natural habitats incl. rivers and lakes	985.6	495.8

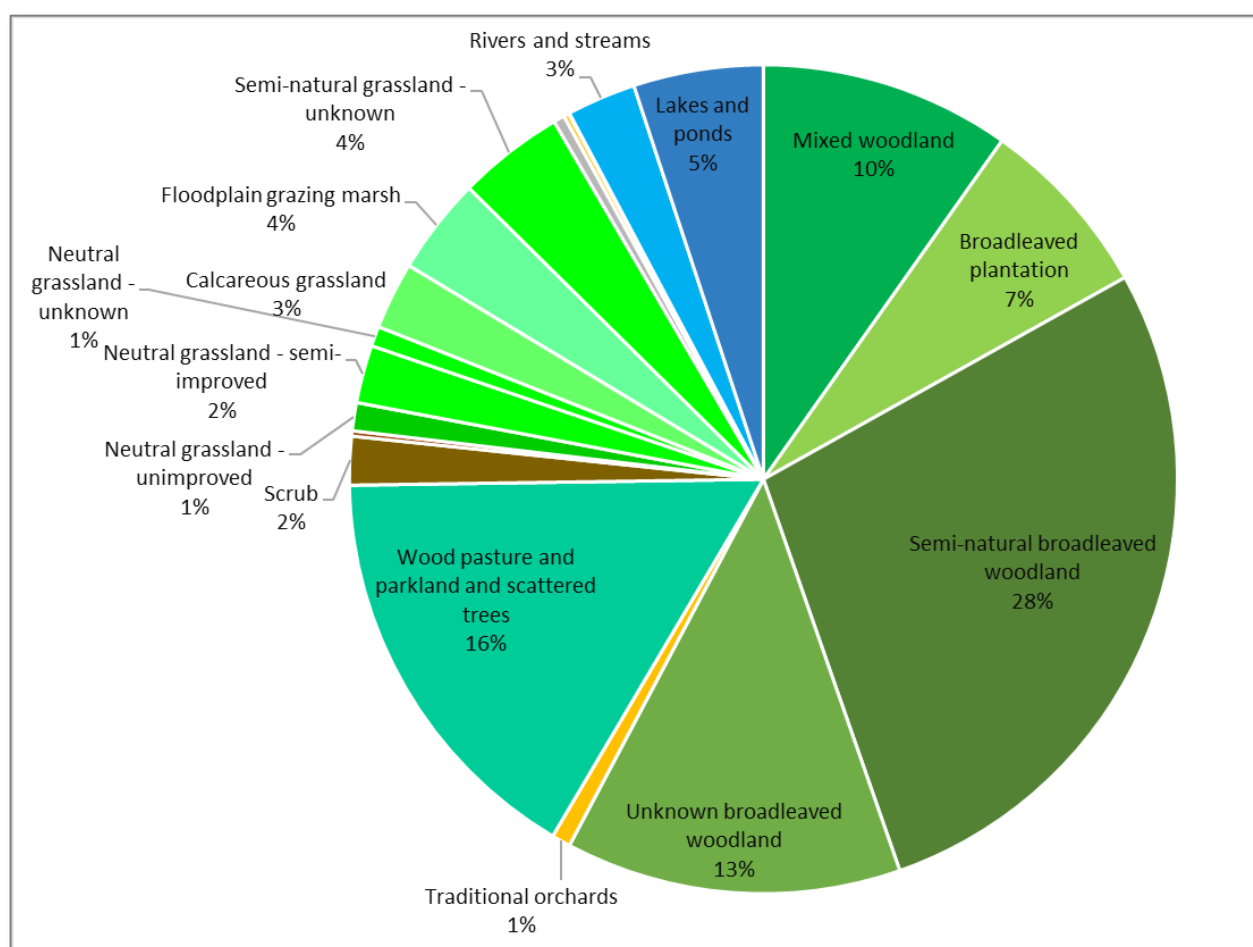


Figure 15. Semi-natural habitats on the Blenheim Estate

4.5.2 Nature and cultural designations

Many of the most important semi-natural habitats occur within designated areas. There are five SSSIs on the estate, as well as six local wildlife sites, one proposed local wildlife site and 20 ancient woodlands (Figure 16). The whole Park is protected as a World Heritage Site (WHS) and Historic Park and Garden. Large parts of the farmland in the west of the Estate are within the Cotswolds Area of Outstanding Natural Beauty, and the southern part is within the Oxford Green Belt.

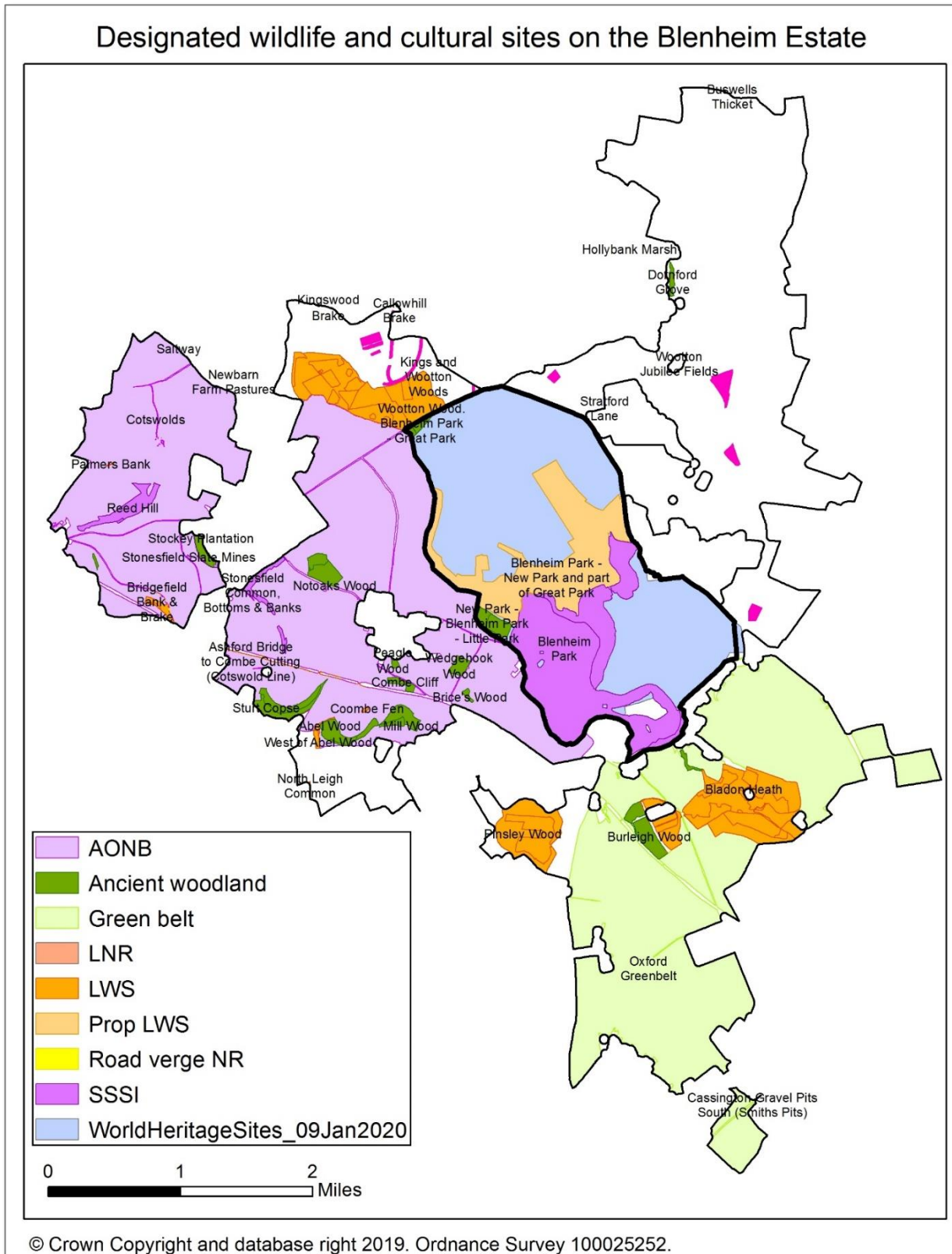


Figure 16. Nature and cultural designations (note: many sites have more than one designation; only one is shown)

The SSSIs are:

- Blenheim Park, covering High Park wood, the Lince (the strip of wood in the south of the Park), the lake, and the wood pasture within Bladon Park. High Park is remnant ancient oak woodland from the Wychwood Forest and contains trees up to 700 years old. This is one of the reasons for the World Heritage Site designation.¹⁷
- Reed Hill: a narrow, sheltered, dry valley containing several unimproved limestone grassland communities, mixed scrub and secondary woodland.
- Stonesfield Common, Bottoms and Banks: a series of steep sided valleys and banks with unimproved limestone grassland and scrub habitats.
- Stonesfield Slate Mines: a geological SSSI
- Sturt Copse: an important relic of the ancient hanging ash-wych elm woodlands of the Evenlode Valley noted for several uncommon plants. It is a distinctive and exceptional example of the few remaining woods of this group on the steep Jurassic limestone slope above the river. Structurally, it is the most intact.

The SSSIs were largely in favourable condition at their last assessments (Table 8), though the lake in the Blenheim Park SSSI is in unfavourable declining condition due to deteriorating water quality (see section 4.4).

Table 8. Sites of Special Scientific Interest on the Estate (ha)

SSSIs	Favourable	Unfavourable recovering	Unfavourable declining	Total (ha)
Blenheim Park	172.03	0.00	52.08	224.11
Reed Hill	14.03	0.00	0.00	14.03
Stonesfield Common, Bottoms & Banks	4.47	7.13	0.00	11.61
Stonesfield Slate Mines	0.17	0.00	0.00	0.17
Sturt Copse	6.45	0.00	0.00	6.45
Total (ha)	197.16	7.13	52.08	256.37

There are eight local wildlife sites on the Estate (Table 9), encompassing a wide range of scarce habitats.

Table 9. Local Wildlife Sites on the Blenheim Estate

Local Wildlife Site	Description	Area (ha)
Bladon Heath	Extensive woodland area, open habitats (grassland, heath) have been mainly lost.	94.80
Bridgefield Bank & Brake		3.06
Burleigh Wood	Ancient woodland. East part with some semi-natural areas some broad leaved plantation, wide rides.	12.59
Coombe Fen	Small area of species rich fen meadow and alder woodland.	0.29
Kings and Wootton Woods	Large ancient woodland with extensive semi-natural areas and diverse open grassland areas.	90.97
Palmers Bank Field margin		0.10
Pinsley Wood	Ancient woodland part semi-natural part replanted.	46.54
West of Abel Wood	Species rich ancient woodland and a few meadow clary in open grassy area. West bank de-notified due to loss of habitat to woodland plantation.	1.84
Total		250.20

4.5.3 Condition of habitats

4.5.3.1 Woodlands, wood pasture and parkland with scattered trees

There are around 310 ha of ancient woodland on the Estate, though many of these sites have been replanted (Table 10).

Table 10. Ancient woodlands on the Blenheim Estate

	Ancient & Semi-Natural Woodland (ha)	Ancient Replanted Woodland (ha)	Total area (ha)
Bladon Heath	40.81	21.34	62.14
Wootton Wood	33.36	17.69	51.05
Pinsley Wood	28.04	18.50	46.54
King's Wood	19.92	20.41	40.33
Burleigh Wood	5.95	19.65	25.59
Worton Heath	7.28	10.45	17.73
Sturt Copse	13.45	-	13.45
Notoaks Wood	7.48	3.10	10.58
Abel Wood/Brook Hill	2.44	6.72	9.16
Mill Wood	1.80	6.58	8.38
New Park - Blenheim Park - Little Park	2.27	5.27	7.54
Wedgehook Wood	3.70	-	3.70
Stockey Plantation	3.32	-	3.32
Combe Cliff	-	2.52	2.52
Dornford Grove	1.89	-	1.89
Brice's Wood	0.86	-	0.86
Peagle Wood	0.74	-	0.74
Kingswood Brake	-	0.14	0.14
Callowhill Brake	-	0.04	0.04
Buswells Thicket	0.02	-	0.02
Un-named ancient woodland areas	3.75	-	3.75
Total	177.08	132.40	309.48

The Blenheim Park SSSI was designated because it “contains one of the finest areas of ancient oak-dominated pasture woodland in the country and is descended from a twelfth century deer park and Anglo-Saxon chase.”¹⁸ When the site was designated in 1986 it was noted that it held “at least twelve species of the vascular plant flora, including meadow saffron *Colchicum autumnale* and sixteen species of epiphytic lichens” characteristic of undisturbed ancient woodland in southern England. The large area of parkland with scattered veteran oak trees in the south east part of Blenheim Park (Lower Park) is outside the SSSI but is listed as Lowland Wood Pasture and Parkland, which is a Section 41 Priority Habitat (formerly Biodiversity Action Plan habitat). The 2014 Parkland Management Plan reported that these trees were generally in good condition but some were suffering damage from soil compaction as a result of mowing too close to the base of the tree with heavy machinery.¹⁵

The ancient and veteran trees in High Park and the surrounding parkland (section 4.2) are a major asset for biodiversity. Large, old trees typically have hollows, cracks and crevices that provide nesting and hibernation sites for birds, bats and invertebrates. The 65 fallen dead trees and 150 standing dead trees identified in the tree inventory provide valuable habitat for fungi and several threatened species of beetle (see section 4.5.4.1). Standing dead wood in particular is extremely scarce in the UK.

The Blenheim Park woodlands are managed in accordance with a Woodland Grant Scheme agreement with an annual programme of thinning and pruning from 2003 onwards.¹⁷ According to the Farm Environment Plan (FEP) survey, carried out in 2011 to inform the Higher Level Environmental Stewardship agreement, High Park was managed in accordance with the SSSI 'Views About Management' (2005) document with the aim of retaining the wood pasture character and protecting the veteran trees.¹⁹ At that stage, bracken was controlled through annual rolling, with rides and grassland areas being mowed rather than grazed. Conifers planted in the 1950s were being gradually removed, following a specialist report produced in 2013, to retain the historic character and nature conservation value. Natural England recommend that the SSSI woodlands should be managed to maintain a "diverse woodland structure, with open space, a dense understory, and a more mature overstory".²⁰ At the last formal SSSI assessment in 2011, the three woodland units were rated as being in favourable condition with good regeneration of oak seedlings and a high diversity of invertebrates, though it was recommended that the grassland areas should be grazed rather than mown.²¹ However, the 2011 FEP survey found that overall the woodland floor was fairly bare and species poor, although it reports that a 2010 BBOWT survey found that the smaller patch of woodland in the north west of the area contains wood melick, false wood brome, wood meadow grass, dog's mercury, bluebell, dog violet and primrose.

The High Park management plan prepared in 2014 (developed for compliance with the Higher Tier Environmental Stewardship award) found that the woodlands were heavily browsed by deer and there was little regeneration of saplings.¹⁰ The plan aimed to gradually restore large parts of the current closed canopy woodland to a more open wood pasture structure, with a mosaic of grassland and scrub.¹⁰ There is a programme of haloing around the veteran trees (removing younger trees that overshadow them), and young trees are being planted to ensure succession. The BSG Ecology survey of the area around the lake in 2019 found that the woodlands had no significant understorey and were not considered to be Priority Habitat¹⁶. Acute Oak Decline is starting to affect a number of the oaks in High Park.¹⁶ A small herd of 40 cattle has recently been introduced to control bracken; this is less damaging than using heavy machinery as it avoids soil compaction which could damage the ancient trees.²⁹

A very detailed four-year survey of High Park is currently in progress, led by Kew Gardens.²² They have currently recorded a total of 2,908 species of fungi, plants and animals (see section 4.5.4), and found that High Park is particularly important for fungi (479 species), lichens (224 species), butterflies (21 species), moths (591 species), beetles (468 species), reptiles and amphibians (7 species), birds (54 species) and bats.

4.5.3.2 Scrub

Scrub is an important habitat and food source for birds, invertebrates and mammals, but is rarely mentioned in the various management plans and survey documents and rarely found on the Estate. The BSG ecology survey near the Lake found small areas of native scrub at the woodland edges and in the drier parts of the reedbeds; the latter will be lost when the lake is dredged.²⁴ The High Park management plan does aim to introduce more scrub as the woodlands are managed towards a more open structure.

4.5.3.3 Grassland

The Farm Environment Plan survey¹⁹ noted that most of the grassland within the park is species poor, but there are some pockets of species rich lowland calcareous grassland. A survey by BBOWT in 2010 to assess whether New Park and part of Great Park could be classified as a Local Wildlife Site found areas of species rich calcareous grassland in the Combe and Icehouse valleys in the eastern and western edges of Great Park, with a wide variety of species including greater knapweed, dwarf thistle, rock rose, field scabious, fairy flax, salad burnet, cowslip, harebell, red clover, lady's bedstraw, yellow rattle, birds foot trefoil, red bartsia, wild parsnip, creeping cinquefoil, meadow vetchling, rough hawkbit, wild thyme and burnet saxifrage.¹⁹

The northern fields were converted from arable to grass in 2010 and are now grazed by around 1000 sheep, managed by Park Farm, with small areas cultivated for game cover crops. The grassland near the Palace and by the lake is managed by mowing, and much of the park is now subject to a Higher Level Environmental Stewardship agreement which includes improving the ecological value of the grassland. However most of the

grassland in the northern fields and around the lake is currently very heavily grazed and species poor, with a short sward.²⁴

A survey of the small grassland areas within the High Park woodlands in 2015 by TVERC²³ found that the varied geology of the site with its bands of limestone, mudstone and sandstone has created a mixture of wet and dry acid, neutral and calcareous grasslands, including small patches of three priority habitats: lowland calcareous grassland, dry acid grassland and lowland meadow. They also found a small amount of Meadow Saffron, a nationally threatened species which is included on the Oxfordshire Rare Plant Register. However much of the area was overgrown with bracken; the recently introduced cattle will help control this.

Coastal and Floodplain grazing marsh habitat is found outside the park along the river Glyme between Woodstock and Wootton, and in the Water Meadows just south of the park along the River Evenlode. Some rare plants have been found, including Meadow Clary (*Salvia Pratensis*) in Abel Wood and at Grintly Hill bridge in 2006, and Green Hounds Tongue at Stratford Bridge woods in 2008, increasing from two flowering plants in 2008 to 18 by 2009.¹⁹

4.5.3.4 Freshwater and wetlands

When Blenheim Lake was designated as part of the SSSI in 1986, it was noted that “the fringing reed swamp dominated by common reed *Phragmites australis* is particularly extensive, and the water violet *Hottonia palustris* is locally frequent.”¹⁸ The FEP survey in 2011 found that aquatic vegetation south east of the lake included lesser pond sedge, water mint, purple loosestrife, skullcap, water dock, water plantain, gypsywort, flag iris, great willowherb, hard rush, meadowsweet, water forget-me-not, reed canary grass, reed sweet grass and hemp agrimony.¹⁹ The 2019 BSG Ecology survey found that the reedbeds are used by water voles but invaded by Himalayan Balsam. They will be destroyed (following translocation of the water voles) when the lake is drained for dredging and then replanted.²⁴

The Rivers Glyme and Dorne were surveyed by BSG Ecology in 2015.¹⁶ The freshwater invertebrates present indicated good ecological quality, but invasive signal crayfish were also widespread. As mentioned in section 4.4, the Blenheim Lake was found to be in a poor condition, suffering from eutrophication, sedimentation and algal blooms. This stopped light from penetrating into the lake, which meant that there were few aquatic plants growing on the lake bed. To protect water quality, the BSG report recommended creating buffer strips of semi-natural grass, shrubs or woodland along the Rivers Glyme and Dorn and grass wild flower buffer strips around the lake, and avoiding use of chemical fertilisers, herbicides and pesticides within 500m of the lake shore.¹⁶ It also suggested re-routing the River Glyme to flow through the water meadows at Woodstock, which are currently inundated only during flood periods, although these meadows lie outside the Estate boundaries.

There are a number of small ponds in the Park which could be of value for biodiversity. Mapleton pond in the north-west of the Park is reported to be in poor condition, with siltation and algal blooms.¹⁵

4.5.4 Species observations

4.5.4.1 Plants

The ongoing High Park biodiversity survey²² has identified:

- 269 taxa of vascular plants (flowering plants and trees, ferns and conifers)
- 479 species of fungi, including *Riopa metamorphosa*, a saprotrophic species associated with ancient oaks.
- 224 species of lichen including two species new to the British list: *Lecanora hypoptoides* on lignum of a fallen hulk, and *Rinodina furfuracea* on a young mature ash, several notable species known at only a couple of other sites in England, including *Rinodina exigua*, and species listed as Vulnerable including *Buellia hyperbolica* and *Biatora veteranorum*.
- 67 species of mosses and liverworts, mostly common woodland species, which is a lower diversity than expected.

4.5.4.2 Invertebrates

When Blenheim Park SSSI was designated in 1986 it was noted that High Park contained several species associated with dead and decaying wood (saproxyllic species), including three beetles listed in the British Red Data Book of Invertebrates: Rove Beetle (*Plectrophloeus nitidus*), Carrion Beetle (*Aeletes atomarius*) and *Rhizophagus oblongicollis*, together with other notable beetle species. The Park was a notable site for pseudo-scorpions, supporting one of the four known British populations of False Scorpion (*Dendrochernes cyrneus*), and Roman snail (*Helix pomatia*), another protected species, was abundant in High Park and The Lince.

A 2002 survey of the wood decay communities in Blenheim Park SSSI by Keith Alexander found over 70 species of saproxyllic invertebrate, including the three Red Book beetles listed above, and 14 Nationally Scarce species.¹⁰ This put Blenheim 23rd nationally on the Index of Ecological Continuity, a system for assessing the conservation importance of ancient parklands and wood pastures based on the wood decay beetles present.¹⁰ Alexander noted that these beetles need flowering shrubs such as elderflower and hawthorn to provide nectar in the summer.¹⁰ A 2014 TVERC survey for the High Park Management Plan found anthills of yellow meadow ant (*Lasius flavus*) in the grassland areas in the south of High Park, together with shells of Roman snail.¹⁰

The ongoing High Park survey²² has so far recorded:

- 80 species of molluscs (though not including the two ancient woodlands species of slugs)
- 36 species of spiders (though no scarce species)
- 352 species of Diptera (flies), 54 species of tree bugs (Hemiptera), all considered fairly common
- 157 species of Hymenoptera (bees, wasps and sawflies)
- 21 species of butterflies, including both of the characteristic 'oak' butterflies, Purple Emperor and Purple Hairstreak, both rarely spotted.
- 591 species of moths including a number of notable species. High Park is a rich site for moths.
- 468 species of beetle including several rare or notable saproxyllics (wood-boring) beetles associated with the ancient oaks, such as *Malthodes crassicornis*, only recorded from c. 20 locations, *Agrilus sulcicollis*, the European oak-borer, maybe a first record for Oxfordshire, *Mordellistena neuwaldeggiana*, *Mycetochara humeralis* and *Tomoxia bucephala*.
- The pseudo-scorpion *Dendrochernes cyrneus* which lives only in hollowing oaks.
- 30 other invertebrate species, including 7 species of dragonflies or damselflies.

4.5.4.3 Birds

Blenheim Lake was designated as being regionally important for breeding birds and of county importance for wintering birds¹⁸. When the SSSI was designated in 1986, 42 species of wildfowl were recorded of which fourteen were regular visitors or breeding residents. The lakes had supported over 1% of the total British wintering population of gadwall since 1977 and had the largest breeding population of great crested grebe in Oxfordshire. Other waterfowl present in significant numbers included pochard, tufted duck, mallard, shoveler and teal, with the lake margins and River Glyme attracting passage waders.

A 12 month Wetland Bird Survey by John Brucker in 2009 recorded over 100 Gadwalls during the last 3 months of the year, as well as wigeon, greylag goose, pintail, garganey, pochard, shoveler, sandpiper, tufted duck, golden eye, little grebe, lapwing, shelduck, kingfisher, herring gull, stock dove, skylark, green woodpecker, sand martin, grey wagtail, dunnoek, fieldfare, redwing, reed bunting and reed warbler.¹⁹

Surveys of the Lake in 2015-18 by BSG Ecology found 32 species of waterfowl including 19 of conservation importance. There were three IUCN red-listed species (pochard, white-fronted goose and herring gull) as well as common sandpiper, green sandpiper, redshank, snipe, kingfisher and pintail.²⁴ There were 12 grey heron nests on the island, which was notable as there are only two other known grey heron breeding sites in Oxfordshire, and eight great crested grebe nests.

Other species recorded in the Park include house sparrow, marsh tit, skylark, song thrush, spotted flycatcher, barn owl and starling. Arable farm bird assemblage targets include corn bunting, grey partridge, lapwing,

yellow wagtail, tree sparrow and turtle dove. The ongoing survey of High Park has so far recorded 54 bird species including peregrine falcons.²²

A large number of pheasants are kept in the High Park woods for shooting. These will have an impact on the woodland floor as they forage, and the High Park Management Plan recommends reducing numbers out of the shooting season if possible.¹⁰

4.5.4.4 Bats

Blenheim Park is home to 14 species of bats. A 2013 study found common and soprano pipistrelle bats throughout the park.¹⁷ Daubenton's bat has been recorded over the River Glyme south of the main lake, torpid brown long-eared bat at the Icehouse in Lower Park and pipistrelle, brown long-eared, Natterer's, Daubenton's and barbastelle around the Grand Bridge.¹⁷ Surveys by BSG Ecology between 2017 and 2019 found at least 11 species of bat using the lake and surrounding habitat, including the nationally rare Barbastelle, lesser horseshoe and Nathusius' pipistrelle bats.²⁴

4.5.4.5 Other mammals

The ongoing High Park survey has found 19 mammal species.²² Three deer species (Fallow deer, Muntjac and Roe deer) use the Park.²² Water voles were observed around the northern and western edges of the lake by the 2015-2019 BSG survey; they will be relocated to the river below the lake prior to dredging of the lake.²⁴ The BSG survey also found badger setts and evidence of otters using the lake, and noted that the Park is likely to be used by hedgehogs and brown hare. Evidence of use by otters has also been found in the River Dorn.⁵¹

4.5.4.6 Amphibians and reptiles

The ongoing High Park survey has found seven species of amphibians and reptiles including widespread slow worms and grass snakes.²² Other protected or rare species found within the Park include great crested newts at Mapleton Pond, adders and common lizards.¹⁷

4.5.5 Summary of biodiversity assets

Blenheim Park contains significant areas of ancient woodland, wood pasture and parkland, with an exceptional collection of ancient and veteran trees, a few fragments of semi-natural grassland, and lakes and rivers. There are important populations of threatened species including bats and water voles; the woodlands have high diversity of lichens and invertebrates; the dead wood habitats are important for fungi and beetles and the lake is important for waterfowl. The available data indicates that there may be opportunities to improve the condition of these assets for biodiversity. In the Park, as well as the problems with pollution and algal blooms in the lake (which are being addressed), the 2010 BBOWT survey indicated that the High Park woodland floor contained little distinctive flora and the BSG survey noted no significant understorey in the woods near the lake. The BSG report¹⁶ also identified opportunities to enhance habitats by creating wildflower buffer strips around the lake. Outside the Park, it is important to preserve the few remaining areas of semi-natural grassland, as some of these areas have been lost to tree plantations at two of the local wildlife sites.

5 Ecosystem services

This section of the report assesses the ecosystem services delivered by natural capital assets on the Estate, using the framework presented in Table 1. We start with an overview of all 18 services, and then look at key services in more detail.

5.1 Overview of ecosystem service supply

We start with a scoping assessment of all 18 ecosystem services using a simple habitat scoring approach⁶. This uses a matrix of indicative scores from 0 to 10 that reflect the ability of different habitat types to deliver each service (Annex 1). For some services we then adjust these generic scores using multipliers to reflect habitat condition or quality:

- For food provision, we have applied a multiplier that takes account of the agricultural land class (i.e. the quality of the farmland);

- For recreation, we apply a multiplier based on the degree of public access (open access, restricted access or no access);
- For aesthetic value, we apply a multiplier of 1.1 if the area is within an AONB.
- For education, interaction with nature and 'sense of place', we apply a multiplier if the area is designated for nature, based on how many designations apply; habitat condition, location and whether there is public access.

After applying the multipliers, all scores are normalised back to a scale of 1 to 10. Individual trees and hedgerows are not included in these scores but they are shown on the ecosystem service maps. Rivers are included because they are mapped in the natural capital map as an area. The impact of paths is taken into account in the recreation scores because areas accessible by path receive a higher score (inaccessible areas score zero).

The scoring system and multipliers have been developed by the University of Oxford and partners over several years, incorporating a literature review of 780 papers²⁵ and a series of stakeholder workshops and expert consultations as part of development of an eco-metric tool for Natural England²⁶. The system is still being refined, but it provides a useful way of producing maps and conducting initial scoping assessments of the impacts of land use change on natural capital. However, it is not a biophysical model and it does not include monetary assessment. Scores for the different services (e.g. carbon storage and recreation) cannot be added together because they are not assessed in common units.

The results (Figure 17 and Table 11) show the scores for each service for the Park, the rest of the Estate outside the Park, the whole Estate, and the whole of Oxfordshire (for comparison). This shows that the scores for the wider Estate outside the Park are generally similar to the scores for the whole of Oxfordshire, while the scores for the Park are markedly different. The wider Estate mirrors the Oxfordshire habitat pattern of intensive farmland with scattered patches of woodland and fragments of semi-natural habitat, while the Park contains a much higher concentration of woodlands and other high value semi-natural habitats, leading to higher scores for all services except food production and water supply. For water supply, the score for the Park is slightly lower than the Oxfordshire average because trees intercept rainwater and prevent it from infiltrating into the ground to recharge groundwater supplies. However, as discussed in section 4.4, the groundwater bodies underlying the Estate are not currently at risk of over-abstraction so this should not be a concern. The scores for the Park are exceptionally high for the cultural ecosystem services, due to the high number of nature and cultural designations and the distinctive semi-natural habitats present on the Park, coupled with the extent of public access for recreation and educational activities.

The higher scores for the Park also elevate the scores for the whole Estate to slightly above the Oxfordshire average for all the services except for food production, where the score is depressed by the higher ratio of woodland to farmland for the Estate compared to Oxfordshire as a whole.

For the Estate outside the Park, although the scores per ha are generally similar to those for Oxfordshire, there are some differences. The score for food production is higher, though not by much, because even though there is a higher proportion of farmland it is mainly Grade 3 or 4, while Oxfordshire as a whole has a higher proportion of Grade 2 land. However this finding is very sensitive to the high multipliers assigned to Grade 1 and 2 land in the scoring system, which are currently very uncertain as data is limited. The scores for wood production, cooling and shading, and air quality and noise regulation are slightly higher than Oxfordshire as a whole because the Estate outside the Park has slightly more woodland (11% compared to 9%), while the scores for erosion protection, pollination, pest control, aesthetic value and interaction with nature are lower because of the high proportion of arable land, which has very low scores for these services.

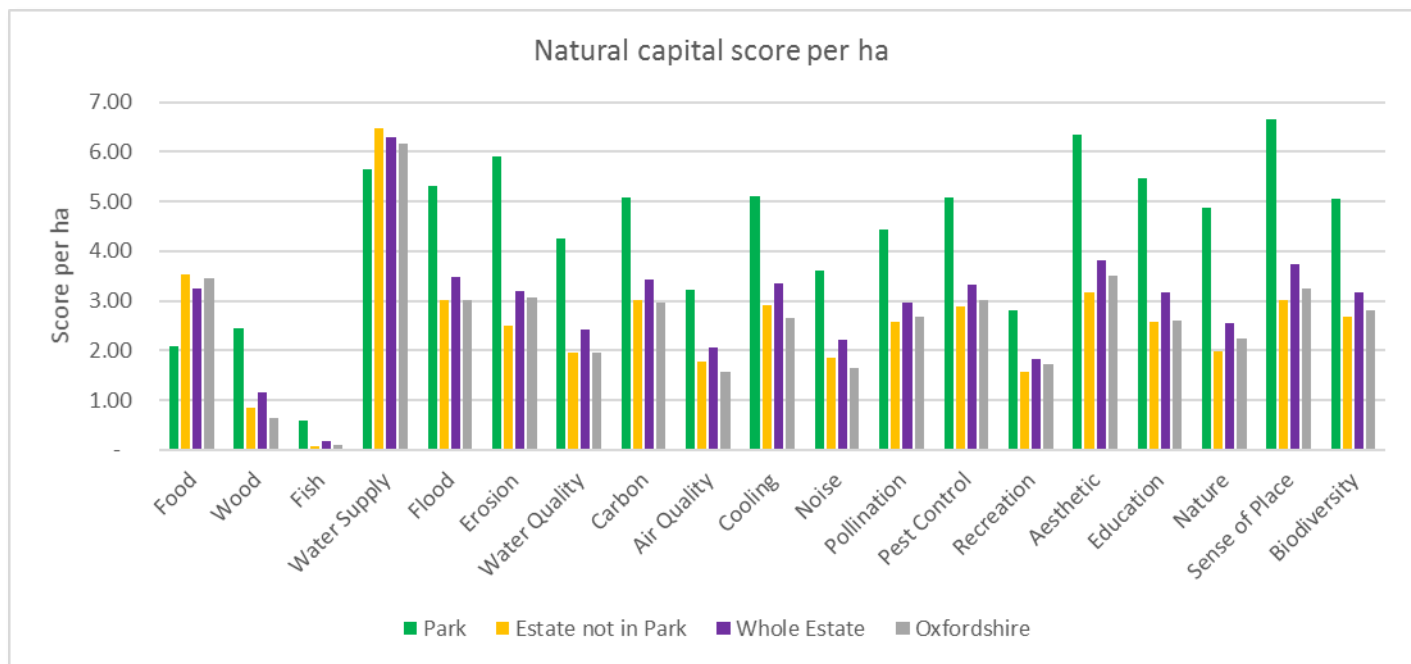


Figure 17. Scoping overview of 18 ecosystem services using a habitat scoring approach

Table 11. Ecosystem service and biodiversity scores per ha for Blenheim Park, Blenheim Estate and Oxfordshire

	Score out of 10 per ha			
	Park	Estate not in Park	Whole Estate	Oxfordshire
Food production	2.10	3.53	3.24	3.47
Wood production	2.45	0.84	1.16	0.64
Fish production	0.59	0.06	0.17	0.11
Water supply	5.65	6.47	6.31	6.16
Flood regulation	5.33	3.03	3.49	3.02
Erosion protection	5.90	2.51	3.19	3.06
Water quality regulation	4.24	1.97	2.42	1.96
Carbon storage	5.09	3.01	3.43	2.97
Air quality regulation	3.22	1.77	2.06	1.57
Cooling and shading	5.11	2.92	3.36	2.66
Noise regulation	3.62	1.86	2.21	1.65
Pollination	4.43	2.58	2.95	2.68
Pest control	5.08	2.89	3.33	3.02
Recreation	2.81	1.57	1.82	1.73
Aesthetic value	6.34	3.18	3.81	3.51
Education about nature	5.47	2.58	3.16	2.61
Interaction with nature	4.89	1.97	2.56	2.24
Sense of place	6.66	3.02	3.75	3.25
Biodiversity	5.06	2.69	3.16	2.80

5.2 Provisioning services: food, wood, water and energy

5.2.1 Food

The overall pattern of food production on the estate is shown in Figure 18, which maps natural capital scores reflecting the ability of different habitats to produce food. All arable land and improved grassland has a basic score of 10 out of 10, but this is then adjusted depending on the agricultural land class. As most of the estate is Grade 3 land, this appears as light green in the map, with the lower quality Grade 4 land in the river valleys appearing in the palest shade of green, and the highest value Grade 2 land in the south east corner in the darkest shade of green.

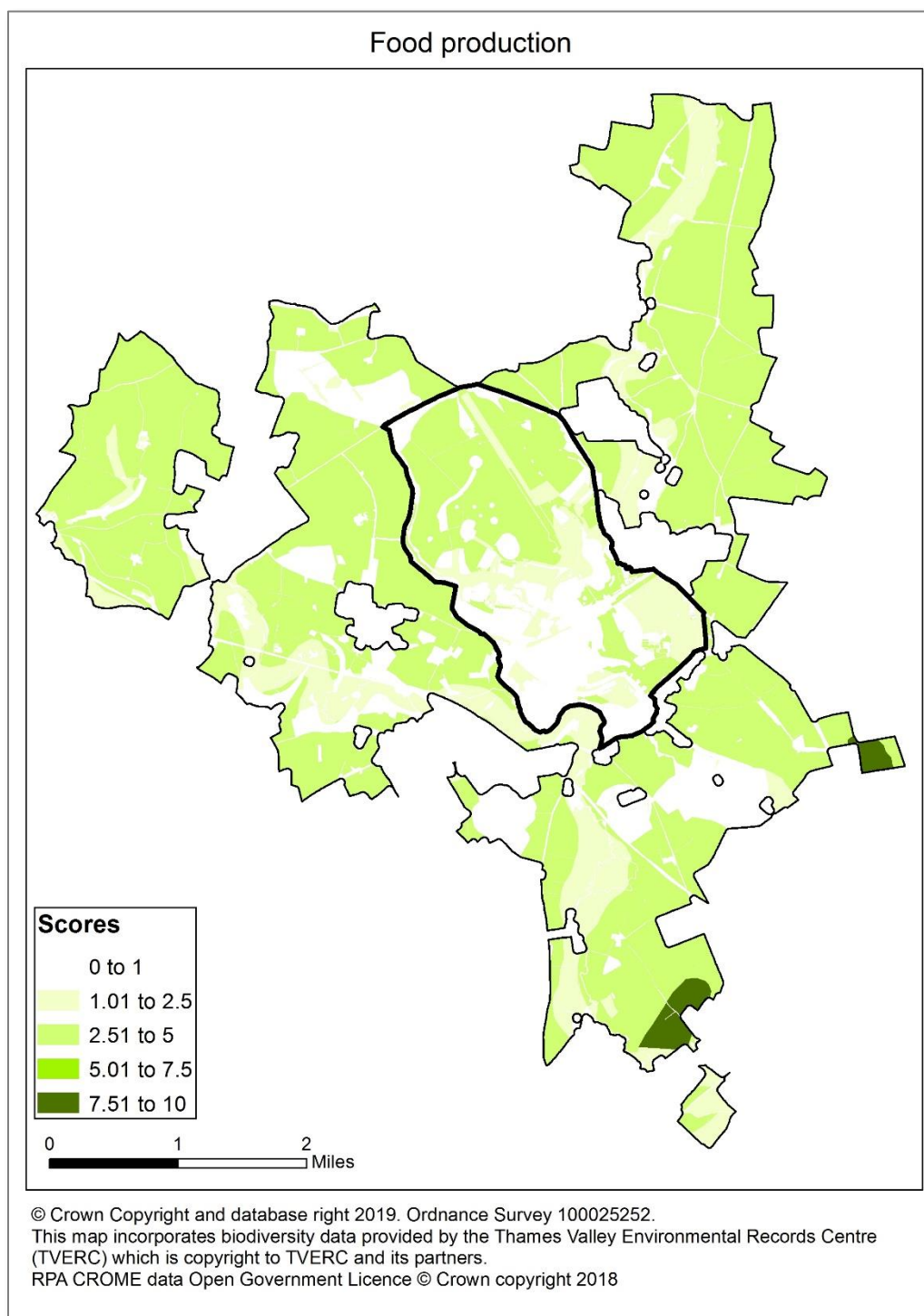


Figure 18. Ability of land on the Blenheim Estate to produce food (crops and grazing) taking account of agricultural land class

5.2.1.1 Arable crops

Around half of the Blenheim Estate is farmed by the Blenheim Farm Partnership (BFP), with the rest being allocated to six different tenants. The BFP farm accounts for 2018 are shown in Table 12.

Table 12. Farm accounts for Blenheim Farm Partnership 2018

	Ha	T/Ha	Tonnes	£/T	£
1st feed wheat	201.53	7.39	1,489	150.02	223,372
Spring barley	164.78	4.73	780	138.01	107,631
<i>Winter oilseed rape</i>	55.32	2.96	164	337.07	55,245
<i>HEAR (High Euric Acid Rapeseed)</i>	81.55	2.40	195	374.91	73,288
Total oilseed rape	136.87	2.63	359	357.66	128,533
Fallow	10.27				
FARM TOTAL	513.45		2,628		459,536
Additional land contracted out for spring barley	168.55	4.73			
Total arable area	682.00				

We do not have accounts for the other tenancies, but we have estimated production based on the Rural Payments Agency's CROME dataset^{9 above}, which maps land use and crop type annually using Sentinel satellite data with some ground truthing from farm inspections. CROME allows us to estimate the area of the estate devoted to producing specific crops in 2018. We have assumed that the other tenancies all achieve the same yields as the BFP for wheat, barley and rapeseed. For other crops identified by CROME, we have used average UK yields for the last five years (2014-2018 or 2015-2019) from Defra's Agriculture UK statistics²⁷.

To estimate the market value we have used the prices per tonne reported in the BFP accounts for wheat, barley and oilseed (assuming the same values for winter and spring crops, in the absence of data), and the prices reported in (or calculated from) the Agriculture UK statistics for the other crops. Agriculture UK does not report yields or prices for maize so we estimated these from other sources. The estimated production of crops from the whole estate for 2018 is shown in Table 13, with a total estimated 16,280 t/y of crops worth around £2.7 million.

Table 13. Estimated production of crops in 2018 for the Blenheim Estate

2018 figures	ha	t/ha	t	£/t	£
Winter Wheat	1,054.13	7.39	-	150.02	-
Spring Wheat	-	7.39	677	138.01	93,404
Winter Barley	143.09	4.73	2,325	138.01	320,856
Spring Barley	491.52	4.73	1,275	357.66	456,004
Winter Oilseed	484.78	2.63	32	376.00	12,002
Spring Linseed	16.20	1.97	-	136.00	-
Winter Oats	-	5.6	286	136.00	38,937
Spring Oats	51.13	5.6	1,134	150.00	170,115
Maize	94.51	12	2,047	172.00	352,131
Potato	44.31	46.2	417	202.38	84,381
Winter Field beans	109.72	3.8	143	202.38	29,024
Spring Field beans	37.74	3.8	142	206.18	29,281
Spring Peas	38.38	3.7	16,269		2,754,795
Total	2,565.51		7,790	150.02	1,168,661

According to the methodology for the UK Natural Capital Accounts²⁸, the natural capital value of food production should use the Resource Rent approach, which subtracts costs and taxes from sales revenue. At farm level, the ONS recommends using the Whole Farm Income which is the total income from agricultural production (excluding subsidies) net of costs (excluding taxes). In the absence of detailed accounts for the

other tenancies, we have estimated the monetary value of food production for the whole estate using the average whole farm income per ha for the BFP (£229/ha) and simply multiplying by the total crop area on the whole estate (Table 14).

Table 14. Whole farm income calculation for arable production by the Blenheim Farm Partnership

		£	£/ha
Total Income from Agricultural production	FARM TOTAL (income)	£459,536	£895
	Other income (mainly straw sales)	£31,372	£61
	Subsidies (basic payment)	£114,083	£222
Subsidies	Subsidies (basic payment)	-£114,083	-£222
Net of costs	Direct costs (seed, fertiliser, sprays)	-£186,687	-£364
	Contract	-£154,035	-£300
	Other contract	-£5,567	-£11
	Other (fuel, property, bank etc)	-£23,455	-£46
	Interest	-£3,713	-£7
Taxes	N/A as calculated before tax	£0	£0
Whole farm income BFP		£117,451	£229

The estimated whole farm income for crop production on the whole estate is therefore:

$$£229/\text{ha} \times 2689 \text{ ha} = \mathbf{£615,158}$$

5.2.1.2 Grazing

There are around 1,550 ewes on the Estate producing about 2,700 lambs each year. Of those, around 1,000 graze the northern fields of the park with the remainder grazing grassland to the south of the park or elsewhere on the estate. The improved grassland to the south west of the Palace (in the Palace gardens zone) is grazed during the winter and cut short during the summer for car parks. Almost all of the 168 ha of semi-natural grassland and 160 ha of wood pasture on the estate is also grazed by livestock. The High Park area in south-west of the Park (ancient wood pasture now mapped as woodland with grassy rides) is grazed by up to 40 British White cattle to control bracken²⁹.

The UK Natural Capital Accounts (NCA) do not include farmed animals, because these are considered to be 'produced assets' rather than natural assets. However the accounts do include the food eaten by farmed animals, including grass and feed. Therefore the measure of food production by grazing for the natural capital accounts should be based on the amount of grass consumed by grazing livestock.

We have used two approaches to estimate the annual amount of grazed biomass consumed by livestock. The first approach multiplies the pasture area by estimates of typical dry weights of grazed biomass per hectare for different types of grassland; i.e. it estimates the supply of biomass. The second approach starts from the numbers of livestock and estimates the amount of biomass they would need to consume per year; i.e. it estimates the demand for biomass.

Estimate 1: Estimated biomass produced per hectare (supply side approach)

Estimates of biomass per hectare for different types of grassland are taken from the Eurostat Material Flow Accounts (Table 15)³⁰. These are based on data from Austrian grassland systems, as no data could be found for the UK.

Table 15. Typical grazed biomass yield of permanent pastures, from the Eurostat Material Flow Accounts³⁰

	Yield (t/ha at 15% moisture content)	
	Range	Average
Rough grazing, alpine pasture	<1	0.5
Extensive pasture	1-5	2.5
Improved pasture	5-10	7

Source: The values are derived from data for Austrian grassland systems

A layer of potential grazing areas was created by selecting all the improved grassland, semi-natural grassland and parkland with scattered trees on the Estate and then deleting very small areas (less than 50m²) which are too small for grazing; many of these are slivers created by boundary mismatch at the edge of the map. The grazing areas in different zones are shown in Figure 19.

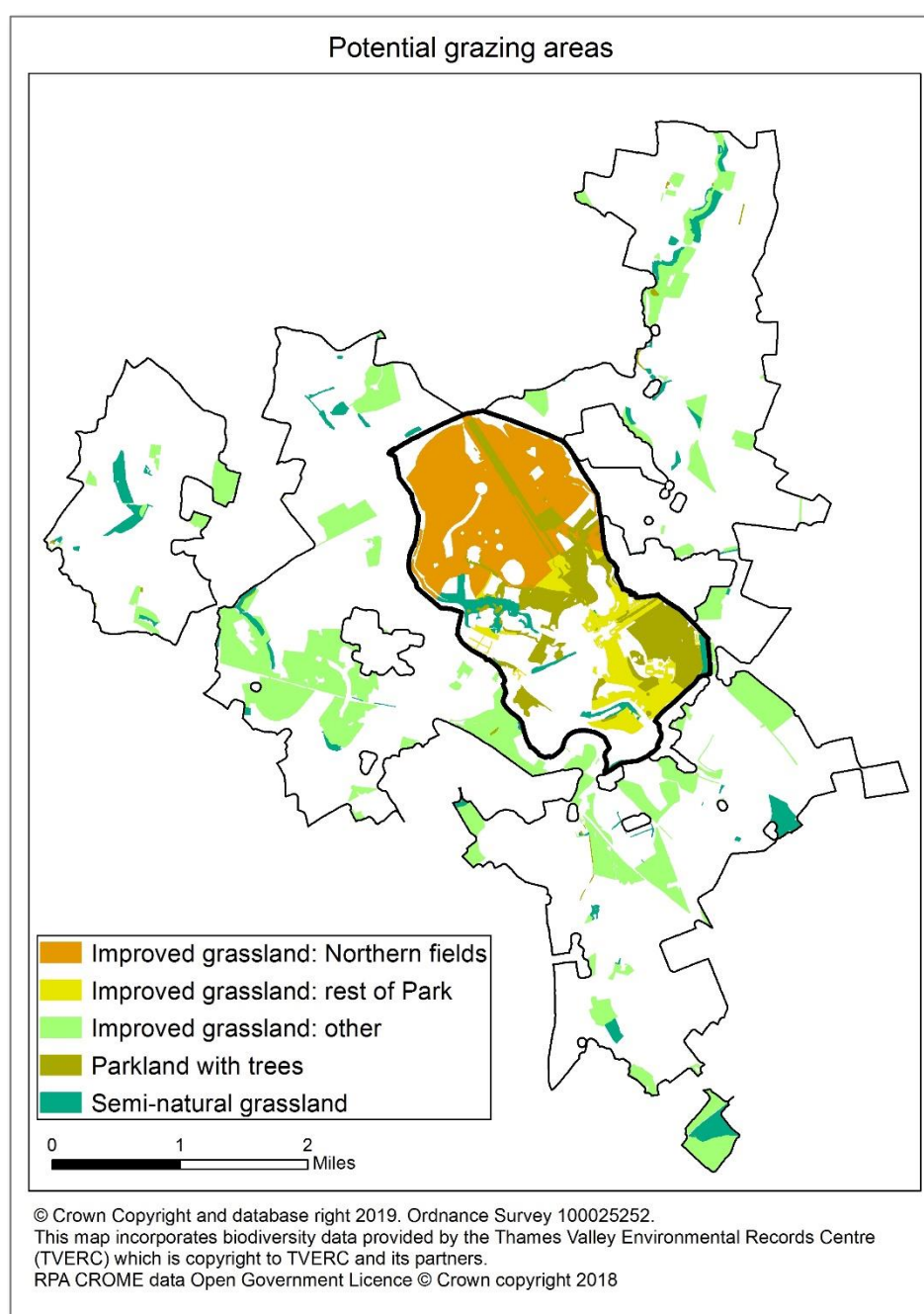


Figure 19. Potential grazing areas

We matched the different habitats to the estimated biomass production values in Table 15, assuming that improved grassland is equivalent to intensive pasture; parkland with trees is equivalent to extensive grazing

and semi-natural grassland is equivalent to rough grazing. Multiplying the estimated average biomass produced by these different types of grassland (Table 15) by the areas of the different types of pasture that are assumed to be grazed on the Estate results in a central estimate of around 6,817 tonnes of grazed biomass produced per year on the Estate, with a wide uncertainty range of 4,728-10,010 t/y (Table 16). However, some of these areas will not be grazed and some may only be grazed for part of the year, so this is probably an upper bound.

Table 16. Estimates of grazed biomass production on the Blenheim Estate: supply-side approach

			Low	Central	High
Biomass production	Improved grassland	t/ha	5	7	10
	Semi-natural grassland	t/ha	0.25	0.5	1
	Parkland with trees	t/ha	1	2.5	5
			Low	Central	High
Zone	Habitat	ha	t/y	t/y	t/y
Northern fields	<i>Improved grassland</i>	305	1,523	2,133	3,047
Gardens	<i>Improved grassland</i>	37	185	259	370
Other zones	<i>Improved grassland</i>	564	2,822	3,951	5,645
Total estate and park	Improved grassland	906	4,531	6,343	9,061
Total estate and park	Semi-natural grassland	147	37	74	147
Total estate and park	Wood pasture and parkland	160	160	401	802
Total estate and park	All potential grazing	1,214	4,728	6,817	10,010

Estimate 2: Estimated grazed biomass required by livestock on the Estate (demand side approach)

A breakdown of the assumed livestock numbers for the different grazed areas of the Estate is given in Table 17.

Table 17. Assumed livestock numbers on the Estate

	Total	Northern fields	Other grassland and parkland	High Park
Ewes	1,550	1,000	550	
Lambs	2,700	1,742	958	
Cattle	40			40

Estimated feed (roughage) requirements per animal are again taken from the Eurostat Material Flow Accounts (Table 18).

Table 18. Typical roughage intake by grazing animals in Europe, from Eurostat material flow accounts³⁰

	Daily intake (kg/head/day)	Annual intake (t/head/year)	
	Range	Range	Average
Cattle	10-15	3.6-5.5	4.5
Sheep and goats	1-2	0.35-0.7	0.5
Horses	8-12	2.9-4.4	3.7
Mules and asses	5-7	1.8-2.6	2.2

Feed requirements have been estimated for lambs assuming that they require half the requirement of sheep, as they are only grazed for part of the year. This assumption should be checked.

Low, central and high estimates of the feed requirements taken from Table 18 were multiplied with the estimated number of livestock from Table 17 as shown in Table 19. The central estimate for the total biomass demand by the 1550 ewes and 2700 lambs on the Estate is 1,450 t/y, in a range of 1,015 to 2,030 t/y. Of this,

the demand from the 1000 ewes and the proportional number of lambs (1,742) in the Northern fields is 935 t/y, with the demand from the remaining 550 ewes and 958 lambs being 515 t/y. The demand from the 40 cattle is estimated as 648 t/y, in a wide range of 144 to 3654t/y.

These estimates of biomass demand can be compared with the areas of grazing land available. The demand for 935 t/y in the Northern fields is met by an area of 305 ha of improved grassland, so the demand is 4.3 t/ha. However there are far fewer sheep grazing on the rest of the Estate, with a demand of just 0.83 t/ha. This is consistent with the fact that the Northern fields are known to be very intensively grazed, while the rest of the Estate includes more extensive grazing habitats (semi-natural grassland and parkland with scattered trees). This calculation is not done for cattle, which graze in the woodland and pasture areas of High Park, because the exact area is not known.

The estimated biomass demand of 4.30 t/ha/y from the Northern fields is just below the low end of the Eurostat estimate of 5 to 10 t/ha potential production for improved pasture, showing that the two methods are consistent, i.e. estimated demand does not exceed estimated supply. For the rest of the estate, demand is well below potential supply, but much of the grazing in these areas is aimed at maintaining the biodiversity value of semi-natural grassland and parkland rather than intensive food production.

Table 19. Estimates of grazed biomass production per ha in Blenheim Park: demand-based approach

Roughage requirements		Low	Central	High		
Ewes	t/head/y	0.35	0.50	0.70		
Lambs	t/head/y	0.18	0.25	0.35		
Cattle	t/head/y	3.60	4.50	5.50		
Demand for biomass	head	t/y	t/y	t/y	ha	t/ha/y
Ewes: northern fields	1,000	350	500	700	305	2.30
Lambs: northern fields	1,742	305	435	610	305	2.00
Subtotal Northern fields		655	935	1,310	305	4.30
Ewes: other	550	193	275	385	872	0.44
Lambs: other	958	168	240	335	872	0.38
Subtotal Other		360	515	720	872	0.83
Total ewes and lambs	4,250	1,015	1,450	2,030	1,214	1.67
Cattle	40	144	648	3564	n.k.	n.k.
Total	4,290	1,159	2,098	5,594	n.k.	n.k.

In summary, the central estimate of total annual grazed biomass on the Estate is 6,817 t/y from the supply side approach, including all potentially grazed habitats, and 2,098 t/y from the demand-side approach, including demand from ewes, lambs and cattle. The central value from averaging these two approaches is 4,458 t/y. Including the lower and upper bounds of each range of estimates gives a wide uncertainty range of 1,159 to 10,010 t/y.

Table 20. Summary of estimates for grazed biomass production (t/y)

	Low	Central	High
Supply of biomass	4,728	6,817	10,010
Demand for grazed biomass	1,159	2,098	5,594
Mid-point of demand and supply	2,943	4,458	7,802
Overall range (lowest to highest)	1,159	4,458	10,010

5.2.2 Wood

Timber and biomass is produced from the woodlands on the Estate and the biomass is burnt for heat and power generation. An inventory of each woodland compartment and sub-compartment is held in a MyForest database, which records the typical age of trees, the species mix and the planned schedule of thinning, felling and restocking for the next 10 years. The actual volume of timber or biomass harvested each year is not recorded, but if it is assumed that a sustainable cut would extract 70% of the annual incremental growth each year, the Estate woodlands could support an annual extraction of 2,623 tonnes of wood (Table 21).

Table 21. Estimated potential sustainable wood production from the Estate woodlands

Woodland Type	Area (ha)	Typical Yield Class	Annual Growth (m3)	Annual sustainable cut (m3)
Conifer plantation	160	8	1,278	894
Mixed woodland	96	6	578	405
Broadleaved plantation	70	4	281	197
Semi-natural broadleaved woodland	274	4	1,094	766
Unknown broadleaved woodland	129	4	517	362
Traditional orchards	7	-	-	-
Total woodland	736		3,748	2,623

In future it should be possible to apply a monetary valuation to the service of wood production. The Office for National Statistics (ONS) approach for the UK Natural Capital Accounts is based on the stumpage price, i.e. the value of standing timber if an area was sold to a third party prior to harvesting. The average price for coniferous standing sales was £28.22 per cubic metre overbark standing in nominal terms in the year to March 2020, and the average price for softwood sawlog sales was £54.06 per cubic metre overbark, according to the Forestry Commission Coniferous Standing Sales Price Index.³¹ However the methodology published by the ONS²⁸ is not complete, and a number of methodological issues would need to be addressed in order to arrive at a clear valuation. Questions to be addressed include:

- Whether the standing sales price is applicable to annual removals, or whether it should only be applied to standing timber stock;
- What valuation approach to use for removals from non-coniferous woodlands;
- Whether it is necessary to distinguish between wood used for timber from that used for biomass;
- How to deal with pruning or thinning as opposed to felling of the whole tree.

These issues could be addressed in future development of this assessment.

Figure 20 shows the ecosystem service map for wood supply, based simply on assigning the maximum score of 10 for conifer plantations and lower scores for semi-natural woodland and hedgerows, which are not suitable for felling but can provide some material from thinning and pruning.

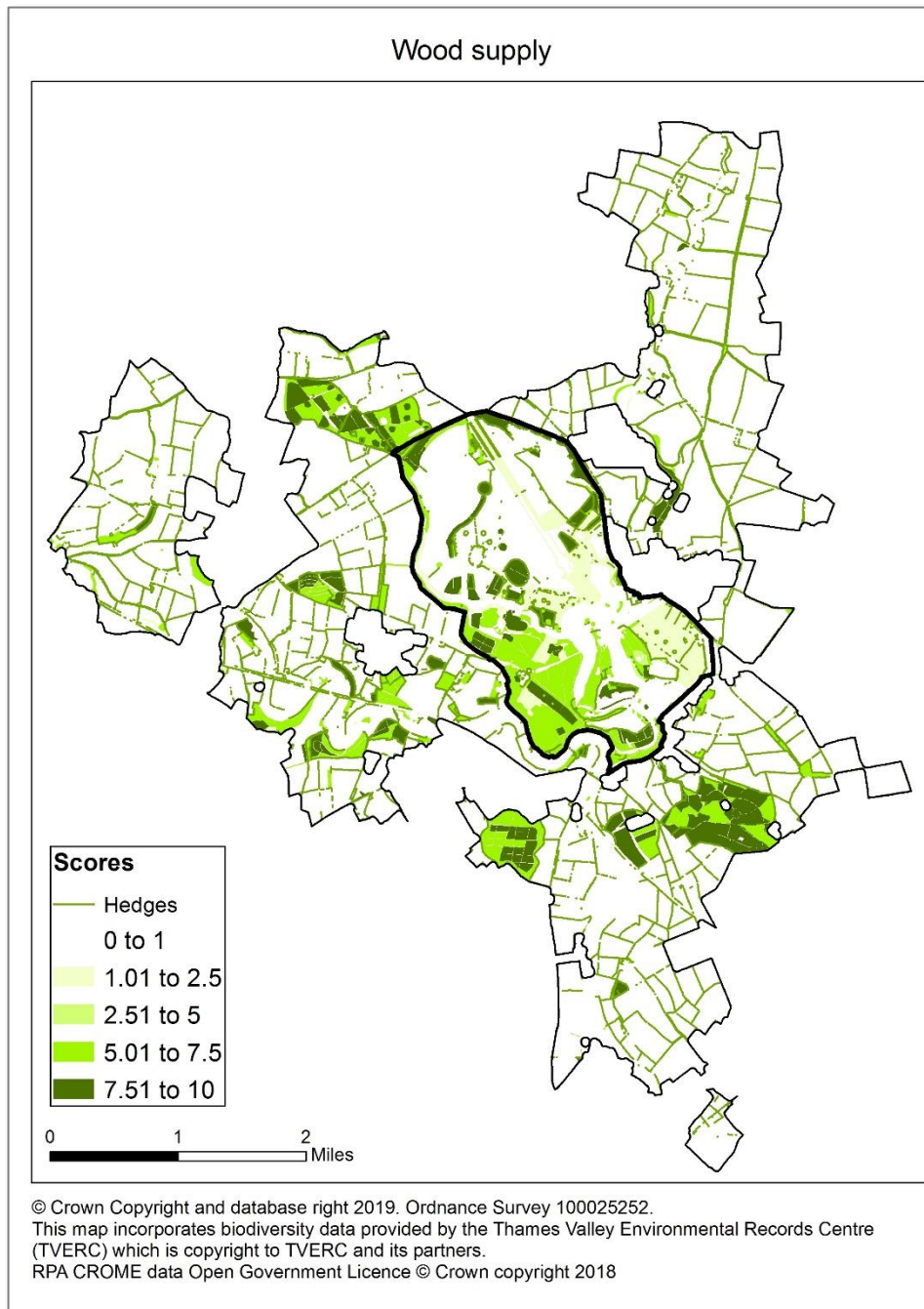


Figure 20. Potential wood supply at Blenheim

5.2.3 Water

Mineral water is produced on the Estate and sold via Love Water, currently producing 1.4 million litres in glass and 1.98 million litres in cooler bottles per year³². According to the economic impact report by Oxford Brookes University, the business made a surplus of £1,000 in 2018-2019 and provided a direct economic contribution of £568,000 to the economy, taking into account employment.³³ By 2019-2020 the surplus had increased to £34,000³².

The estate contributes to regional water supplies by enabling rainwater to soak into the ground and recharge groundwater supplies, or sustain surface water supplies via subsurface flow and gradual release back into a stream or river. Any permeable surface will enable this recharge to take place. In contrast, rain falling on impermeable surfaces such as roads and buildings will typically be channelled into the nearest drain and then straight back into a watercourse and out to sea (unless captured in a sustainable drainage system and allowed to infiltrate via a retention basin).

Woodlands have a mixed effect on water supply. Tree roots tend to improve the permeability of the soil, so a large proportion of the water reaching the woodland floor either through rainfall or overland flow will infiltrate into the ground. However, much of the rain falling on woodlands will be intercepted by the leaves of trees and will then evaporate before reaching the ground, and much of the water that infiltrates into the ground will be absorbed by tree roots and eventually released back into the atmosphere through transpiration. This effect is more pronounced for coniferous trees as they are in leaf all year round, while deciduous trees shed their leaves in winter which is the most important season for groundwater recharge in the UK.

Semi-natural grassland will typically have a good soil structure that readily allows infiltration and groundwater recharge, while improved grassland may be more compacted. Cropland is typically very permeable, but some rainwater will be taken up by the crop itself, and also many fields are under-drained and the drainage pipes may channel much of the rainwater into the nearest drain or ditch and then out to the sea.

Our scoring approach (see section 5.1) therefore applies the following scores out of 10 for the ability of different habitats to facilitate water supply: water and wetlands 10; semi-natural grassland 9; arable fields and improved grassland and parkland with scattered trees 7; scrub 4; semi-natural broadleaved woods 3; and conifer plantations 1.

The quantitative status of the groundwater bodies underlying the Estate is currently good, indicating that they are not yet over-abstracted, but climate change and a growing population is expected to increase pressure on water supplies in the south of England in future. Enabling groundwater recharge will therefore continue to be an important service for the Estate to provide. This can be done through minimising any conversion to sealed surfaces, integrating sustainable drainage systems into any new developments, and improving the condition (reducing compaction) of arable and grassland.

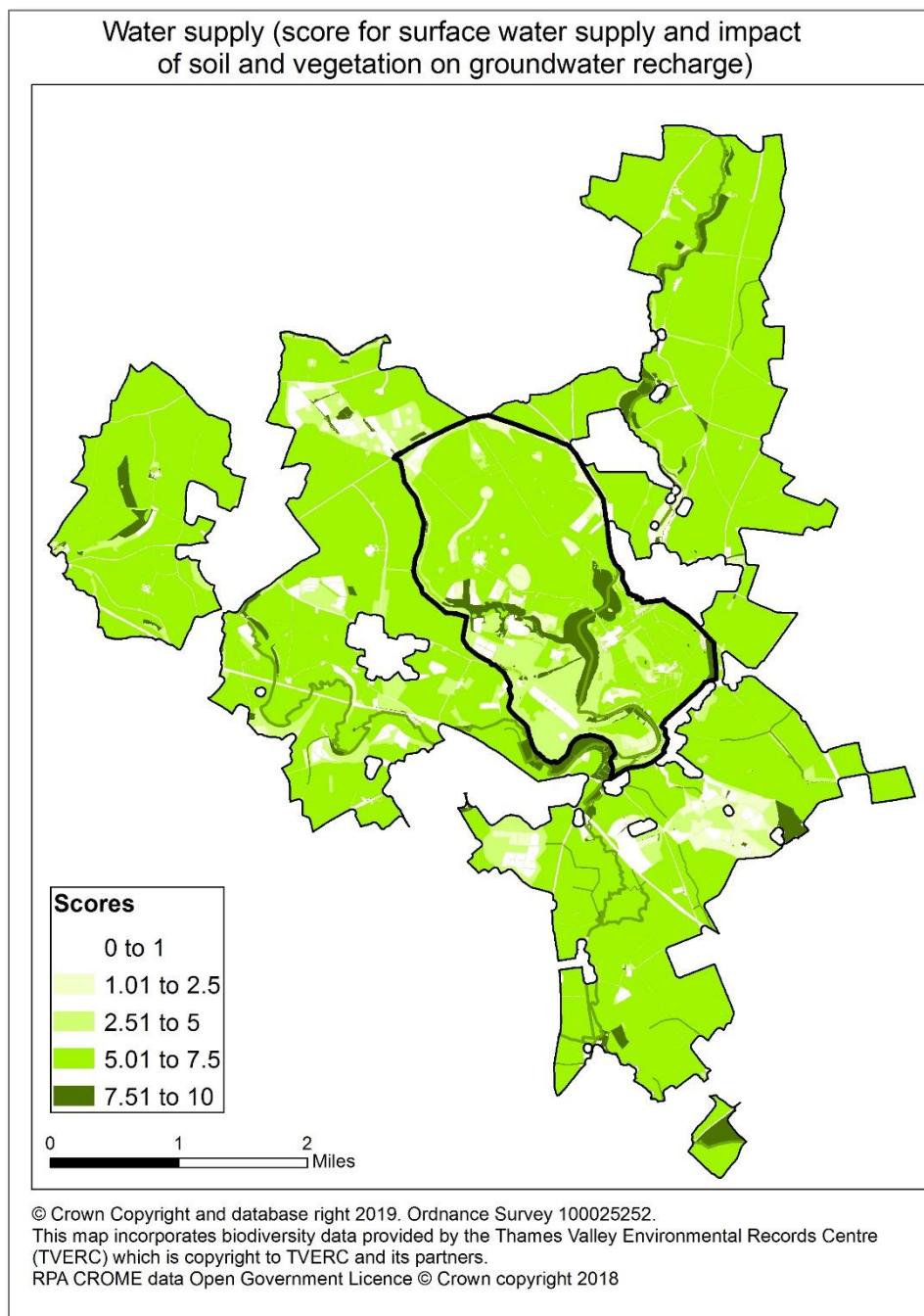


Figure 21. Ability of land on the Blenheim Estate to enable water supply through groundwater or surface water recharge

5.2.4 Energy

The estate produces hydro-power, bio-energy (from biomass harvested from the estate woodlands) and solar power, but we do not have data on annual production. Although solar power is not an ecosystem service, and cannot be directly influenced by management of the estate, it is included in the UK Natural Capital Accounts because it is considered to be derived from abiotic natural capital (sunlight).

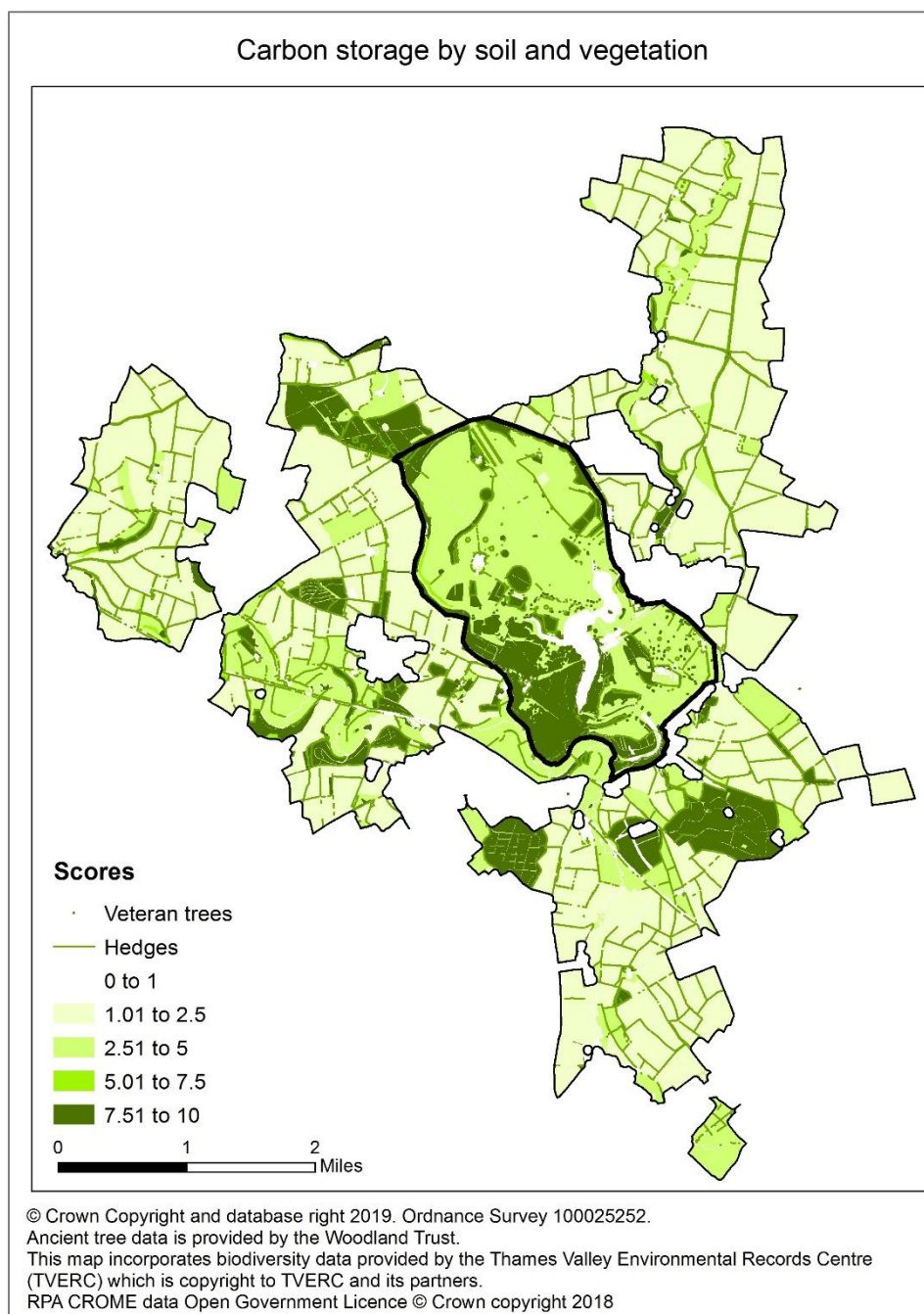
5.3 Carbon storage and sequestration

Figure 22 maps the carbon stored by soils and vegetation on the estate using the habitat scoring approach. Scores are based on generic estimates of the average amount of carbon stored in different habitats in southern England taken from a published literature review by Cantarello et al³⁴. The review lists average carbon storage values for selected habitats, and we have extrapolated these figures to include other habitats not listed in the review.

The map highlights the value of the woodland areas, which store the most carbon, as well as the individual ancient trees in the Park. It also shows the difference between the arable fields (where soil carbon is depleted

by cultivation) and the grassland areas in the park and along the river valleys where soil carbon is expected to be higher.

Figure 22. Carbon stored by soil and vegetation



We have estimated the amount of carbon stored in soils and vegetation on the estate, using the figures in the Cantarello et al review³⁴. This results in an estimate of 453,916 tonnes of carbon stored on the estate (Table 22).

We used the projected non-traded price of carbon as recommended by the UK government natural capital accounting methodology.²⁸ The value for the year 2020 was obtained from the Green Book guidance³⁵ (£69.28 / tonne carbon) and converted from 2018 to 2019 prices using the GDP deflator³⁶ to give a price of £70.58 per tonne carbon. This equates to a monetary value of around £32 million for carbon stored by soil and vegetation on the Estate. However, it is important to be aware that this carbon price is based on estimates of the price required to achieve the Kyoto agreement target of limiting the average global temperature rise to 2°C, and it has not been updated to reflect the price required to achieve the commitment to a net zero target in line with the Paris Agreement.

The table also shows estimated carbon taken up (sequestered) annually, using generic carbon sequestration rates from a Natural England report NERR043³⁷ together with assumptions for additional habitats. It is important to note that estimates of carbon stored and sequestered in different habitats vary widely, so there is considerable uncertainty in these figures. In particular, a number of habitats can produce net emissions of greenhouse gases, depending on how they are managed. For example, arable farming can result in net loss of carbon from the soil due to oxidation following disturbance by ploughing. Similarly, degraded wetlands can release stored carbon as their sediments dry out. A number of habitats that can have either positive or negative emissions were assigned a sequestration rate of zero to reflect this uncertainty.

Of the 1282 trees recorded in the combined Ancient and Veteran Tree Inventory (see section 4.2), 1070 had complete species, location and size information and could therefore be assessed using the iTree-Eco model³⁸. The iTree-Eco model estimated that those trees store 7,219 tonnes of carbon, worth £509,545 at current UK non-traded carbon prices (£70.58 for the year 2020 in 2019 prices, see above), and sequester 21.93 tonnes per year, worth £1,548/year. This carbon will already be partly included in the estimated total for the estate, as part of the estimates for woodland and parkland with scattered trees, so it cannot be added to the carbon stored in habitats. However the generic estimates for carbon stored in woodland will not fully account for the exceptional number of very large trees in Blenheim Park. Further carbon will be stored in the 258 km of hedgerows and linear woodland features on the Estate but this has not yet been assessed.

Note that 15 trees in the inventory were too large to be assessed correctly by iTree-Eco. These trees were assumed to have a diameter of 254 cm, the largest that can be calculated due to lack of reliable data on larger trees. Hence the actual carbon storage by these trees has been underestimated.

Table 22. Estimated tonnes of carbon stored and sequestered in soil and vegetation on the Blenheim Estate

	Area	Carbon stored		Carbon sequestered		Source
	Ha	t/ha	t	t/ha/y	t/y	
Broadleaved and mixed semi-natural woodland	422	273	115,173	1.64	690	NERR043 'Unmanaged forest nature reserve'
Broadleaved and mixed plantation	147	246	36,100	3.00	441	NERR043 'Close to nature forestry'
Wet woodland	1	273	140	1.64	1	Same as broadleaved semi-natural
Coniferous plantation	160	218	34,817	3.00	479	NERR043 'Close to nature forestry'
Felled woodland	1	140	208	-	-	
Traditional orchards	7	137	938	0.03	0	NERR traditional orchards
Scrub	18	164	2,900	0.82	14	Half broadleaved woodland
Hedge maze	0	46	22	0.10	0	Assumed very low
Parkland with scattered trees	144	137	19,659	0.86	124	25% broadleaved woodland, 75% semi-nat grass
Scattered trees: broadleaved	13	96	1,268	0.47	6	25% broadleaved woodland, 75% improved grass
Scattered trees: mixed	3	116	360	0.47	1	25% broadleaved woodland, 75% improved grass
Scattered trees: coniferous	0	136	54	0.47	0	25% conifer woodland, 75% improved grass
Semi-natural grassland	85	110	9,308	0.60	51	NERR semi-natural grass
Calcareous grassland	26	82	2,129	0.60	16	NERR semi-natural grass

	Area	Carbon stored		Carbon sequestered		Source
	Ha	t/ha	t	t/ha/y	t/y	
Marshy grassland	37	109	4,065	0.60	22	NERR semi-natural grass
Improved grassland	905	82	74,431	0.24	217	NERR improved grass
Improved grassland and scattered scrub	1	96	58	0.30	0	Higher than improved grass to reflect scrub
Arable	2,689	62	147,115	-0.25	-660	NERR043 arable
Allotments	2	55	91	-	-	Assume zero as may be a source or a sink
Amenity grassland	22	55	1,228	0.24	5	NERR improved grass
Bridge - natural	0	18	0	0.24	0	NERR improved grass
Garden	14	18	258	0.24	3	NERR improved grass
Flower bed	0	37	8	-	-	May be a source or a sink
Wetland	2	164	387	-	-	May be a source or a sink
Reedbed	4	109	464	-	-	May be a source or a sink
Lakes, canals and drains	53	27	1,447	-	-	
Rivers	27	5	133	-	-	
Disused quarry	0	18	2	-	-	
Track	32	37	1,154	-	-	
Sealed surface	42	-	-	-	-	
Total	4,858		453,916	1.64	1,412	
Value			£32,036,641		£99,686	
Individual ancient trees¹			7219		21.93	iTree-Eco
Value			£509,545		£1,548	
Hedgerows	Not yet assessed					

¹ estimates for ancient trees are implicitly included in woodland and parkland estimates so should not be added to the total

We have also conducted a more detailed estimate for the woodland areas using the information in the MyForest database for the Estate, which includes species and age for each woodland compartment on the Estate, together with carbon lookup values from the Forestry Commission's Woodland Carbon Code (WCC) spreadsheet tool. We simplified the assessment by taking only the first listed species and age class for each compartment, even though many of the compartments contain mixed species. We also had to make assumptions for the tree spacing, yield class and thinning regime for each compartment. The WCC tool allows a very limited choice of tree spacings between 1.4 and 3m depending on the species. Where there was a choice we chose the largest spacing, and we chose mid-range yield classes. There is a choice of Thinning or No thinning, and this makes a very large difference to the results (see Table 23). The MyForest database does not include the woodland areas in the gardens behind the Palace, so we have added an estimate of the carbon stored and sequestered using the same generic factors as in Table 22. The table also shows the comparison with the estimates using the generic factors (sub-total of woodland from Table 22). This falls within the range of estimates from the MyForest data.

Table 23. Assessment of carbon stored and sequestered in Estate woodlands using the MyForest database and the Woodland Carbon Code calculator

	Carbon stored in trees and debris (tC)	Sequestration tC/y
No thinning	187,490.54	1,518.08
	£12,989,344.60	£105,172.42
Thinning	90,970.91	648.66
	£6,302,464.59	£44,939.05
Extra woodland not in MyForest	17,739.26	123.44
Total without thinning	205,229.80	772.10
Total with thinning	108,710.17	1,641.52
Woodland sub-total from previous table	186,228.83	1,611.09

5.4 Air quality regulation

Figure 23 shows the overall pattern of the service of air quality regulation on the estate, which is provided mainly by trees, shrubland and hedges. Air quality in the Blenheim area is generally reasonably good, but the estate's woodland will still play a role in trapping pollution such as ground-level ozone and nitrogen dioxide that drifts considerable distances across the country.

We have not yet carried out a quantitative evaluation of the amount of air pollution removed each year by woodland on the estate, but an iTree-Eco model for just the 1070 ancient and veteran trees that had adequate data estimated that 490 kg/year of air pollution would be removed annually, worth £390/year. This relatively low value partly reflects the low background levels of pollution in the region.

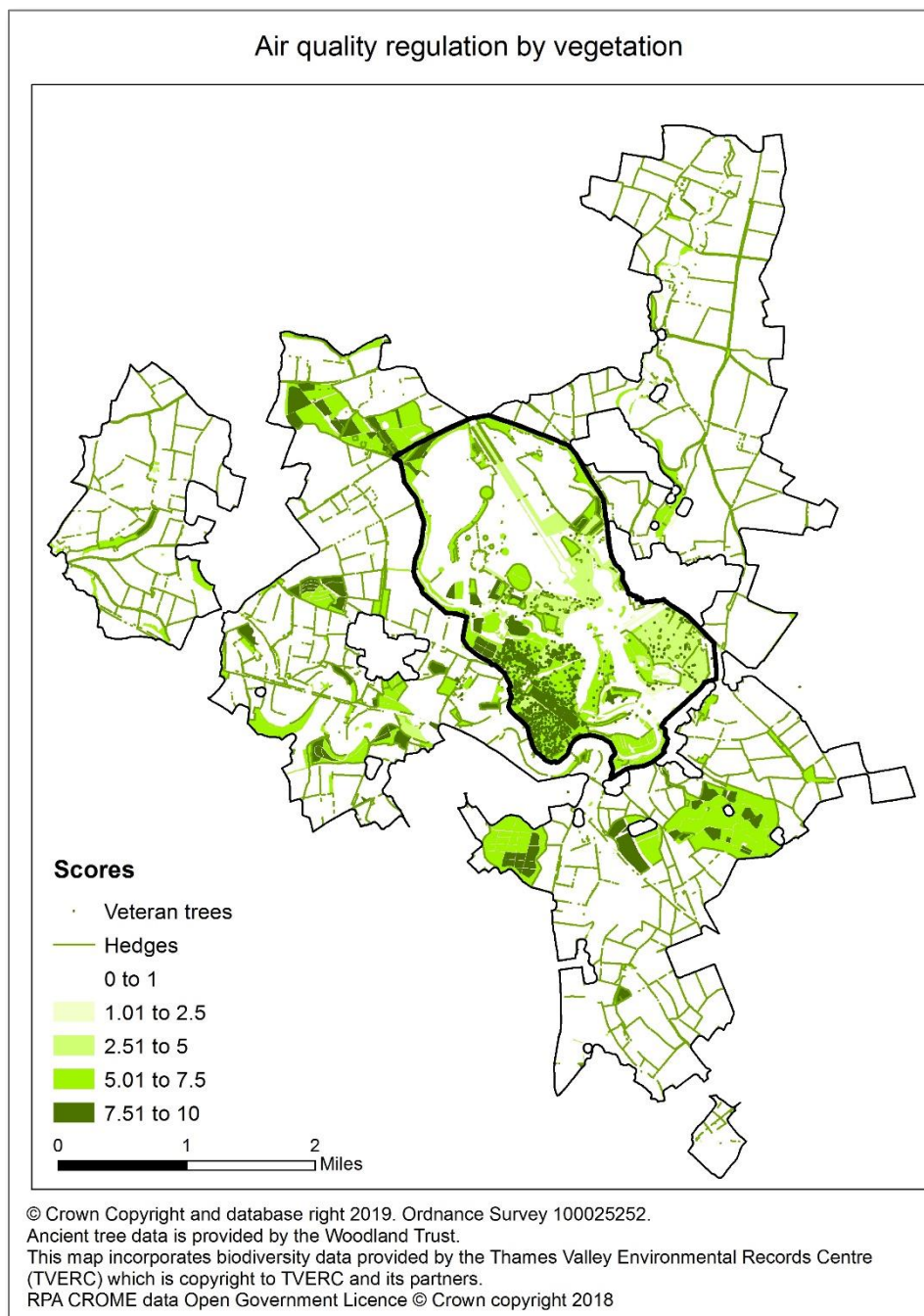


Figure 23. Air quality regulation by vegetation

5.5 Flood protection

The overall pattern of flood protection provided by the soil and vegetation on the Estate is shown in Figure 24. This is very similar to the carbon storage map, as both these services are provided mainly by trees, shrubs and hedgerows, with grassland providing a lower service and arable land a very low service.

The Glyme and Evenlode valleys are highlighted as priorities for flood protection options under the Country side Stewardship scheme.^{39,40}

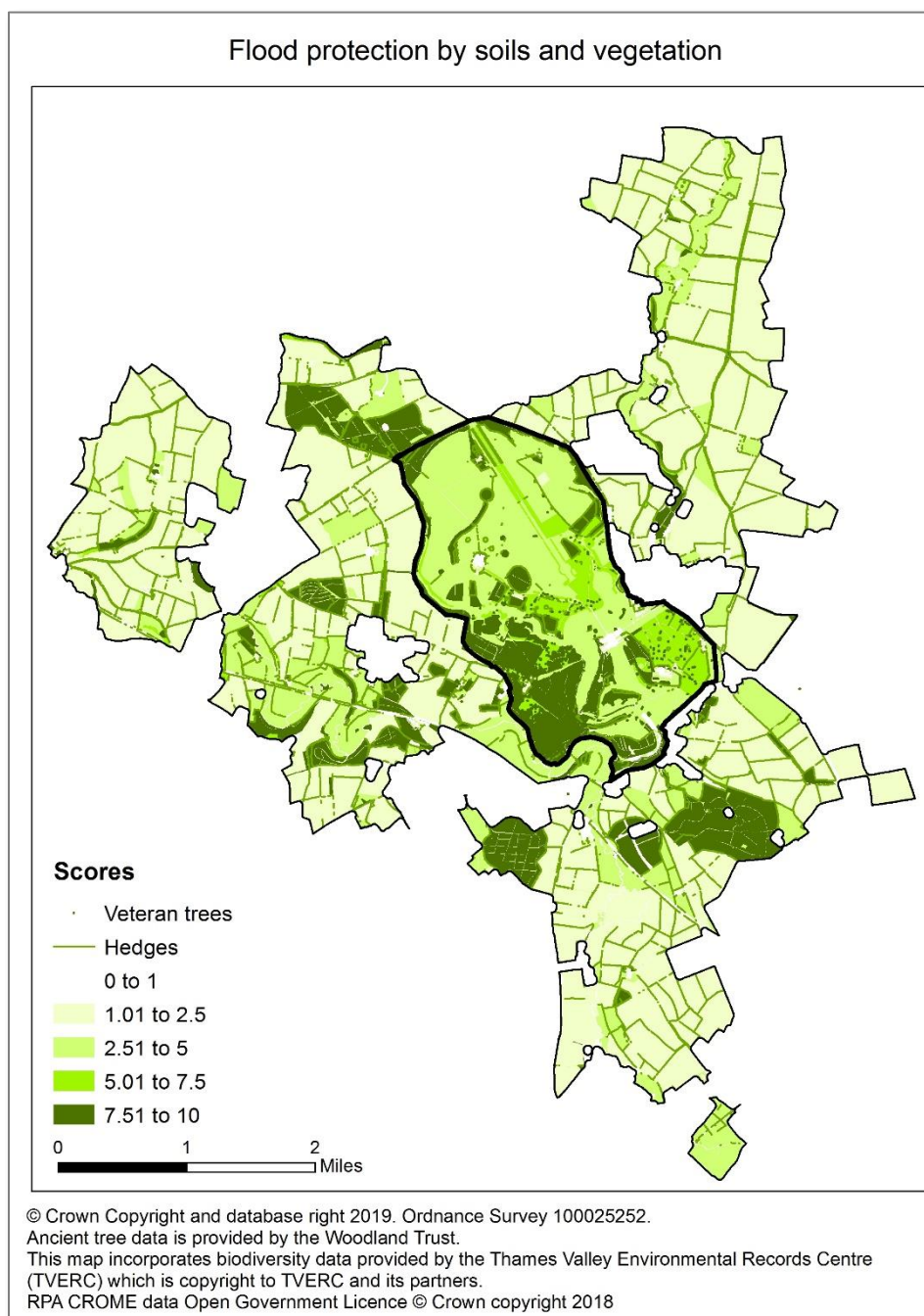


Figure 24. Ability of soil and vegetation to protect against flooding

We have carried out a very simple estimate of the volume of run-off avoided due to the habitats on the Estate, using the NatureTrade model⁴¹ developed by the Plant Sciences group at the University of Oxford. NatureTrade is a demonstration tool and the output should therefore be regarded as indicative. It uses the JULES hydrology model developed by the Met Office to estimate the maximum amount of runoff avoided due to interception and infiltration by vegetation, compared with the amount of runoff which would be produced at this location if the land cover were bare soil⁴². NatureTrade estimates that an annual maximum of 12,390 tons water / hour of runoff is averted from the Blenheim Estate due to the vegetation present. Although the Estate itself is not badly affected by flooding, this service will contribute to reducing flood risk for the communities that live in flood zones downstream of the estate.

The avoided runoff could be monetised using a benefit transfer approach but there would be high levels of uncertainty attached to this estimate. We did carry out an assessment for just the ancient trees on the estate using the iTree-Eco model, which estimated that these trees resulted in avoided runoff of 753.1 cubic meters/year, which is worth £1,140/year in terms of avoided stormwater treatment costs.

5.6 Soil erosion regulation

The overall pattern of the service of soil erosion prevention is shown in Figure 25. This shows the value of woodland and grassland areas and hedges, while the arable areas are generally expected to be a potential source of erosion. Ongoing investigations by Atkins into the reasons why the Blenheim Lakes have silted up have identified a particular erosion risk in the valley of the Glyme to the north-east of the Park.

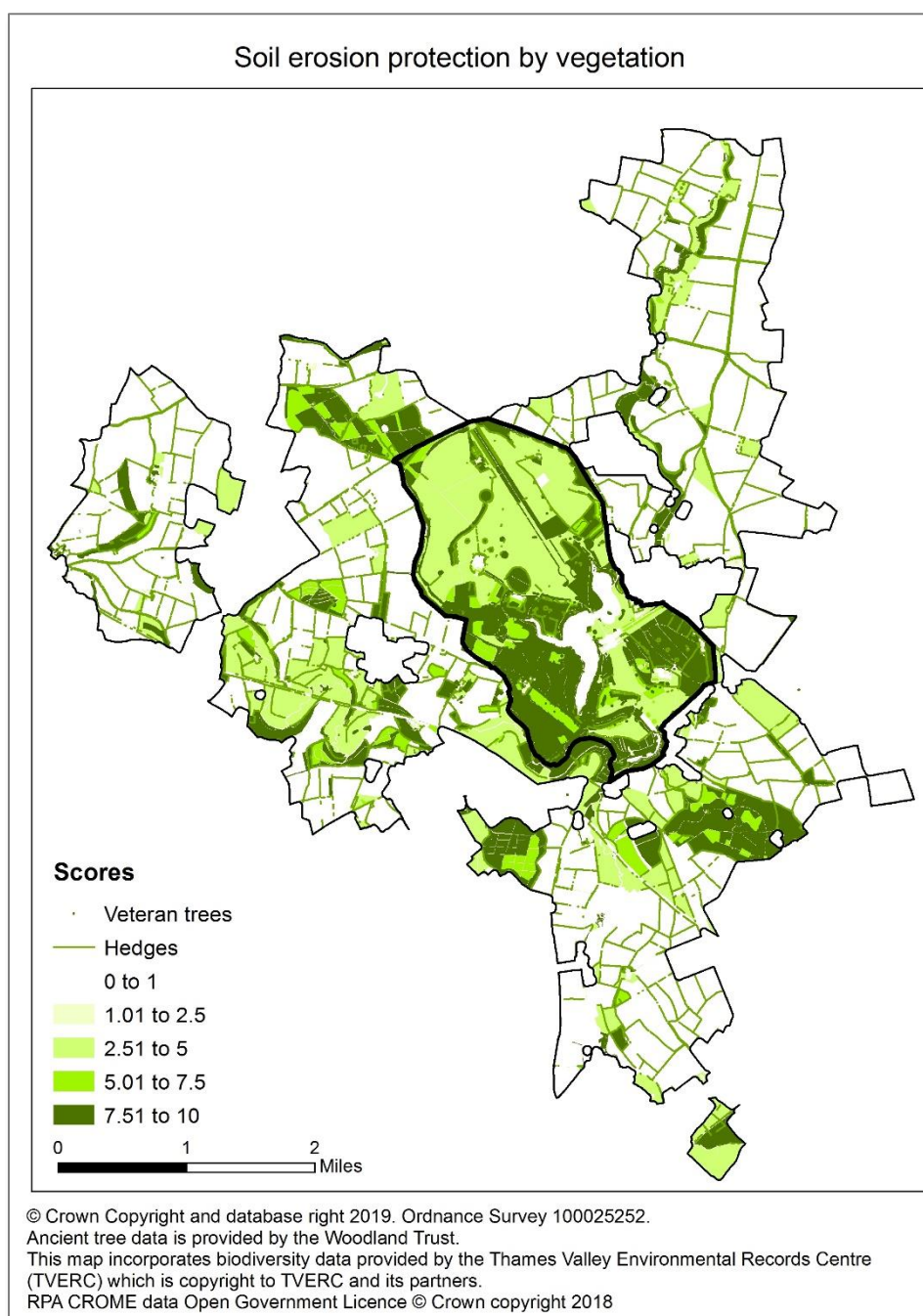


Figure 25. Ability of vegetation to protect against soil erosion and facilitate soil formation

We used the NatureTrade model⁴² to carry out a simple assessment of the amount of avoided soil erosion from the Estate as a result of the land cover. This estimated that approximately 228 tonnes of soil erosion might be avoided each year compared to the amount eroded at this location if the land was bare soil. This relatively low figure reflects the large amount of arable land on the estate.

5.7 Water quality regulation and water supply

Figure 26 shows the general pattern of the service of water supply regulation, through trapping of polluted runoff and sediment by vegetation. This service is carried out by woodland, hedges and semi-natural grassland, while the arable land is expected to be a source of water pollution from agrochemical runoff. It is not currently possible to quantify this service.

Water quality is poor in the Glyme and Dorn rivers and bad in the Evenlode south of the Park, and Blenheim Lakes suffer from phosphate pollution, sedimentation and algal blooms. Most of the Park and the Glyme and Dorn valleys falls within a Countryside Stewardship High Priority Water Quality target area. There are therefore significant opportunities to enhance the service of water quality regulation such as by adding buffer strips of semi-natural grassland, shrubs or woodland alongside the rivers and the Lake, as recommended in the BSG report,¹⁶ or by creating additional woodlands or wetlands along the river valleys (see section 6.2.4).

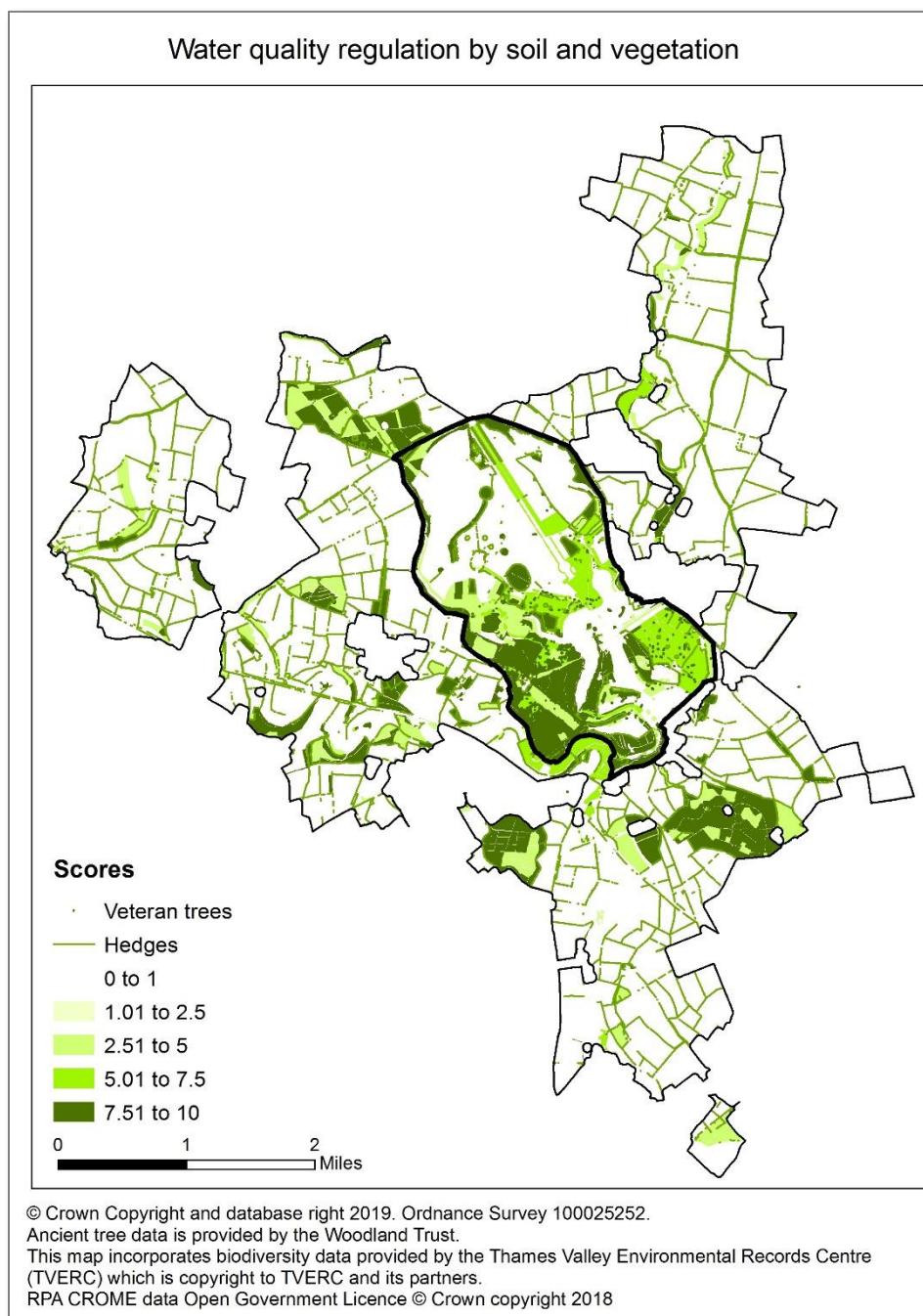


Figure 26. Ability of soil and vegetation to regulate water quality through intercepting, trapping and absorbing pollution and sediment

5.8 Pollination and natural pest control

Semi-natural habitats are essential to provide food and nesting sites for bees, hoverflies and other pollinating insects (Figure 27) and beneficial pest predators such as beetles and spiders (Figure 28), all of which are declining in the UK and more widely. Both pollinators and pest predators require structurally diverse habitats for nesting and hibernation sites, such as tall or tussocky grass, old trees with cracks and crevices, dead leaves and hollow stems. In addition, pollinators require a mix of flowering plants for nectar in the summer. The maps clearly show the value of the semi-natural grassland, scrub, woodland, hedges and parkland. A diverse mix of habitats that can provide both food resources and nesting sites is important, so hedgerows near semi-natural grassland, parkland with scattered large trees and flower-rich arable field margins are particularly valuable

habitats. For pollinators, the nectar resources of semi-natural grassland are critical while for pest predators the structural complexity of scrub, woodlands and hedgerows is the key factor determining the scores.

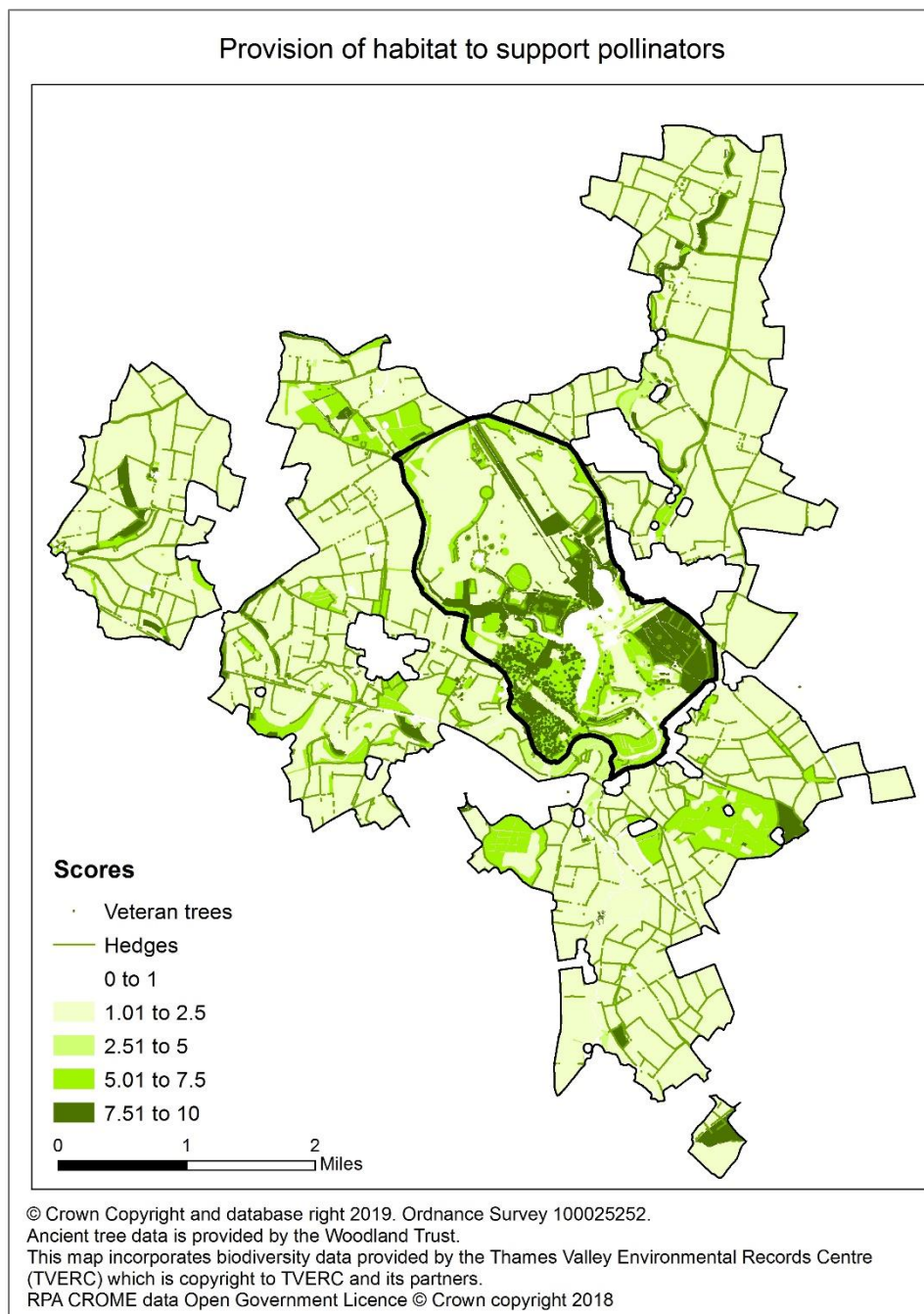


Figure 27. Provision of habitat to support pollinators

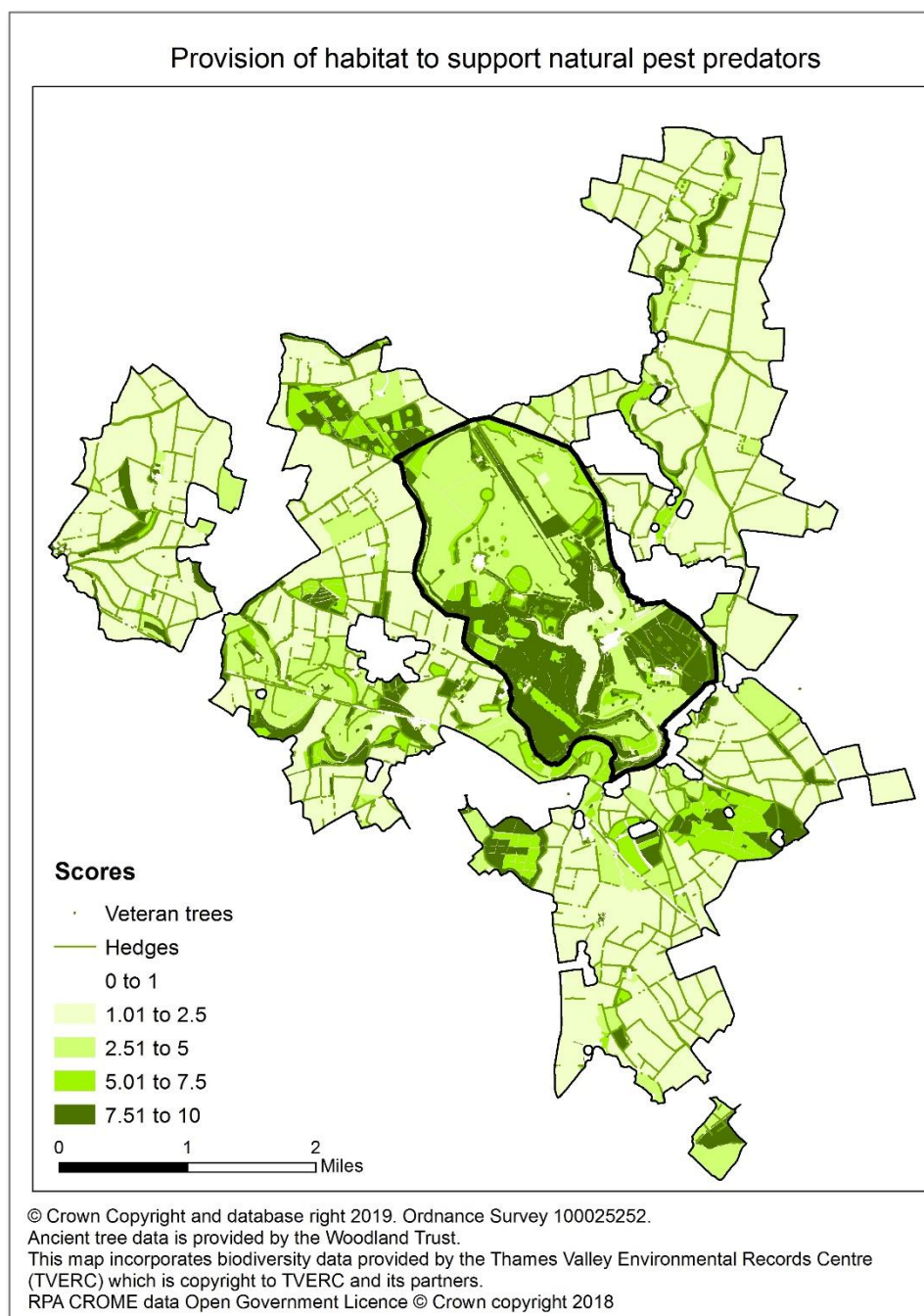


Figure 28. Provision of habitat to support natural pest predators

5.9 Cultural services

We assess five cultural ecosystem services: recreation, aesthetic value, education, interaction with nature and sense of place.

5.9.1 A place for recreation and social interactions

The Estate is crossed by a network of 72 km of public footpaths and 3.5km of off-road cycleways operated by Sustrans, the sustainable transport charity. Footpaths through the Park connect Blenheim with the surrounding villages of Woodstock, Bladon, Combe and Stonesfield. Sections of the Oxfordshire Way and the Wychwood Way run through the park, following sections of Akeman Street, the old Roman road. The Palace, gardens and pleasure grounds are open to paying visitors from early February until December and the Park itself is open between 9.00am and 6.00pm (or dusk) all year apart from Christmas Day. The parkland management plan states that the rights of way are in a good condition and effectively waymarked, and that all areas of the park where visitor access is permitted are well maintained.¹⁷ Blenheim is also used for recreational fishing and

shooting pheasant and partridge, ducks and some deer stalking, mainly for control purposes. Game cover crops are planted in parts of the park and some of the woodlands are used for game rearing and cover.¹⁵

Figure 29 maps the opportunities for recreation within the Estate. The recreational value scores are modified according to public accessibility. Fully accessible areas score the maximum of 10 points for most habitats, especially for grassland and woodland where many different types of recreational activity are possible (walking, running, playing, picnicking etc). The score is a little lower for habitats with less diverse recreational opportunities, such as dense scrub or wetland. Areas with no public access score zero. For areas where only footpath access is possible, we assign a recreational value to a 50m buffer on each side of the public footpath. This is based on the assumption that the experience of path users is likely to be influenced by the habitats within this range of the footpath, with the value of 50m taken from the South Oxfordshire green space strategy⁴³ where a similar (though not identical) process is applied to determine the extent to which footpaths act as green spaces for recreation. Note that a few extra paths that are mapped on Open Street Map but are not identified as public rights of way have been integrated into the map, although whether these are genuinely accessible is not known.

Although members of the public are restricted to public footpaths on the Estate, in practice they can easily access the areas around the lake and the monument from the footpaths, so these are shown as publicly accessible. The gardens behind the Palace are only accessible by those who have paid the entrance fee, although this can be converted to an annual pass at no extra charge, which represents good value for regular visitors. These areas are mapped as semi-restricted, with scores scaled by a factor of 0.75. In addition, some of the Estate woodlands (including Pinsley Wood) are mapped as being publicly accessible according to the ORVal tool (see below).

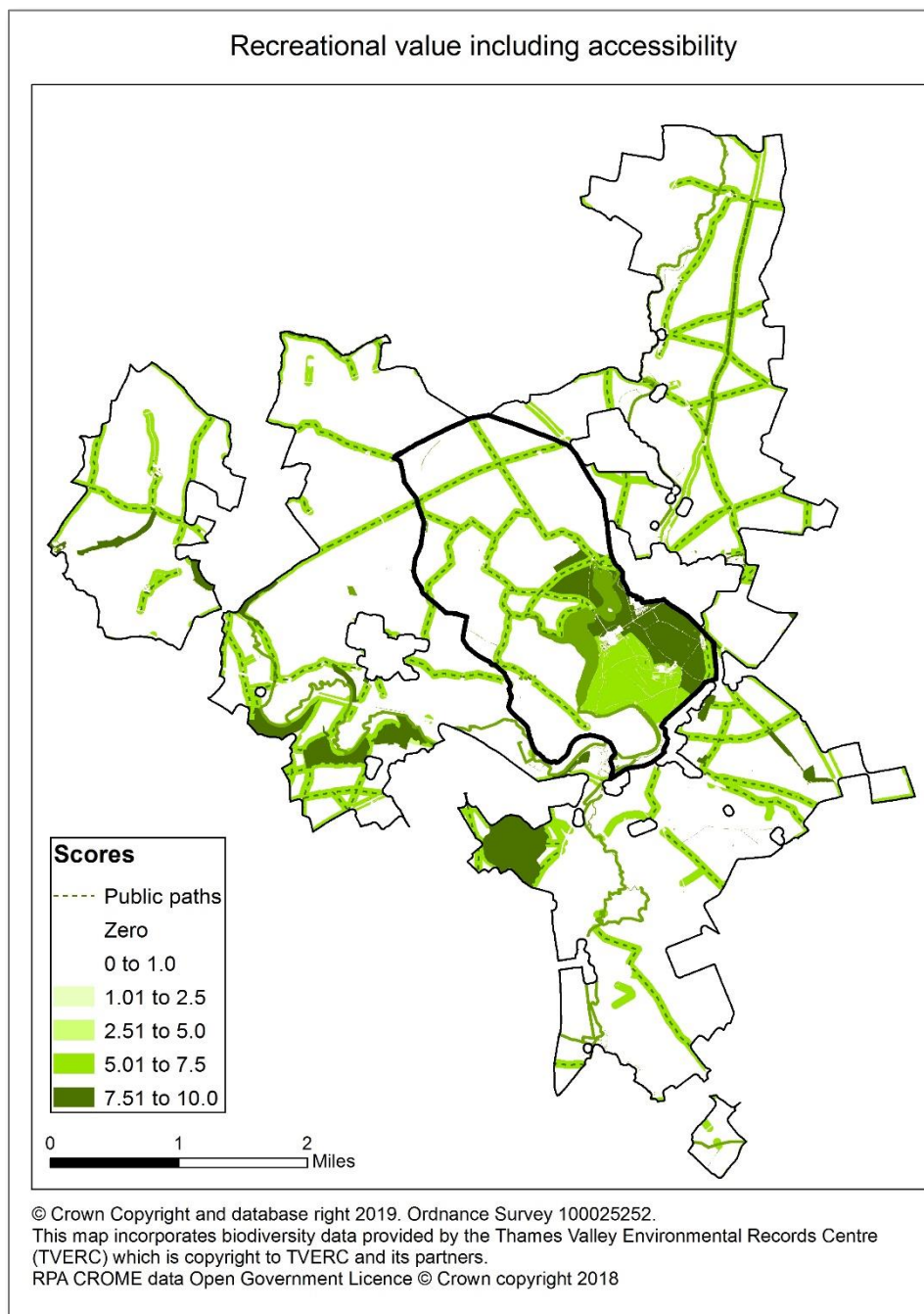


Figure 29. Opportunities for recreation with public access

5.9.1.1 Evidence from the public survey of Park users

We carried out a two-day face-to-face survey in Blenheim Park in September 2019, interviewing 198 parties (360 people). This was followed up with an online survey for annual pass holders in March 2020 which gathered responses from a further 736 people. A full description of the survey results is in Annex 2.

The survey gathered strong evidence of the range of benefits that people get from visiting the Park. Walking was the most popular activity (70% of respondents), even more than visiting the palace, gardens, shop and café (65%), but the park was also highly valued as a place to attend special events, meet friends and family, play with children, and get closer to nature (Figure 30). People visit all parts of the Park but the lake and bridge was most popular, followed by the Palace, shop and café, the gardens, and then the woodlands (Figure 31). Favourite places include the lakeside walk and the bridge, the view point near Town Gate, the cascade, the rose garden, the secret garden, the Harry Potter tree, the bluebell woods and many other places that are special to individual people.

Figure 30. Activities undertaken by survey respondents at Blenheim Park (360 face to face and 736 online annual passholder responses, total 1096 responses)

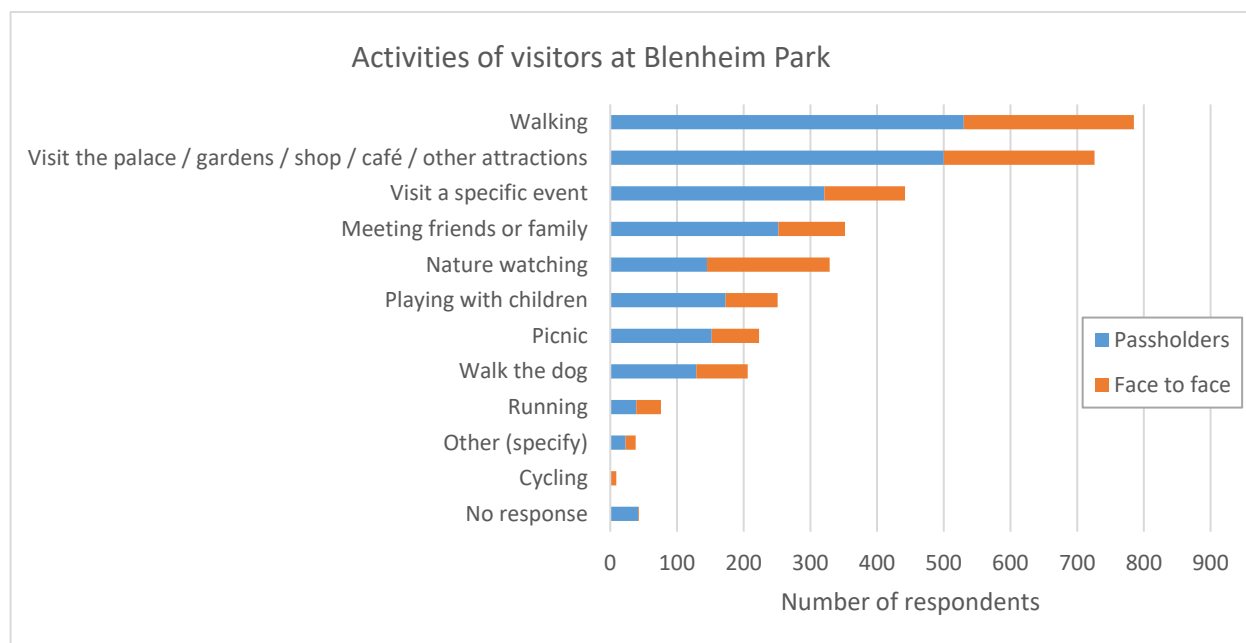
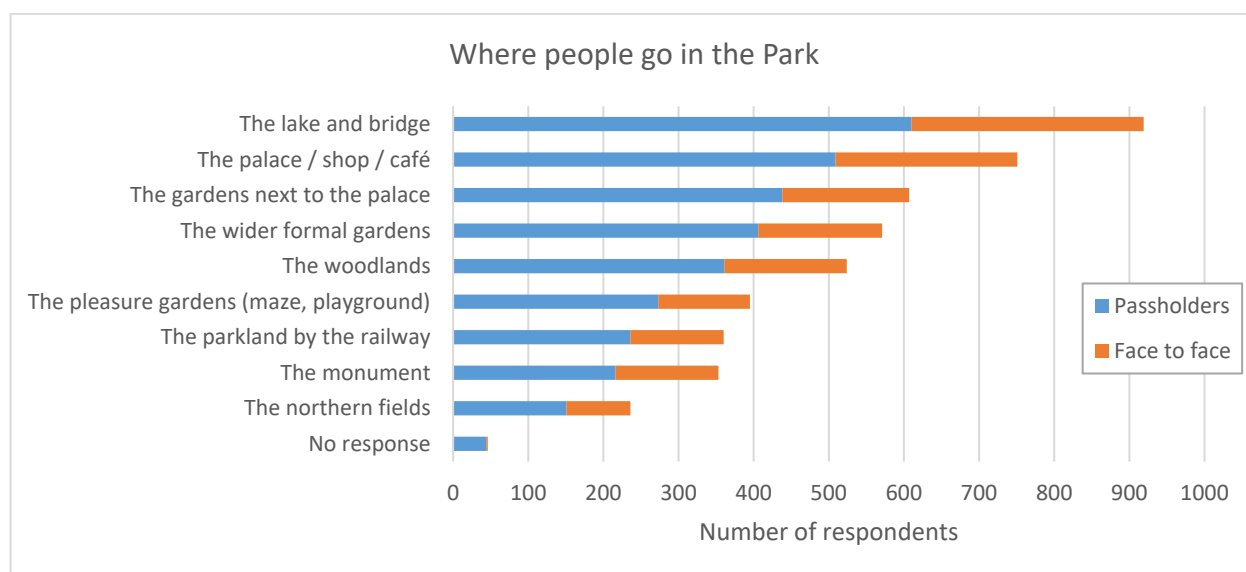


Figure 31. Which parts of Blenheim Park are visited by the survey respondents?



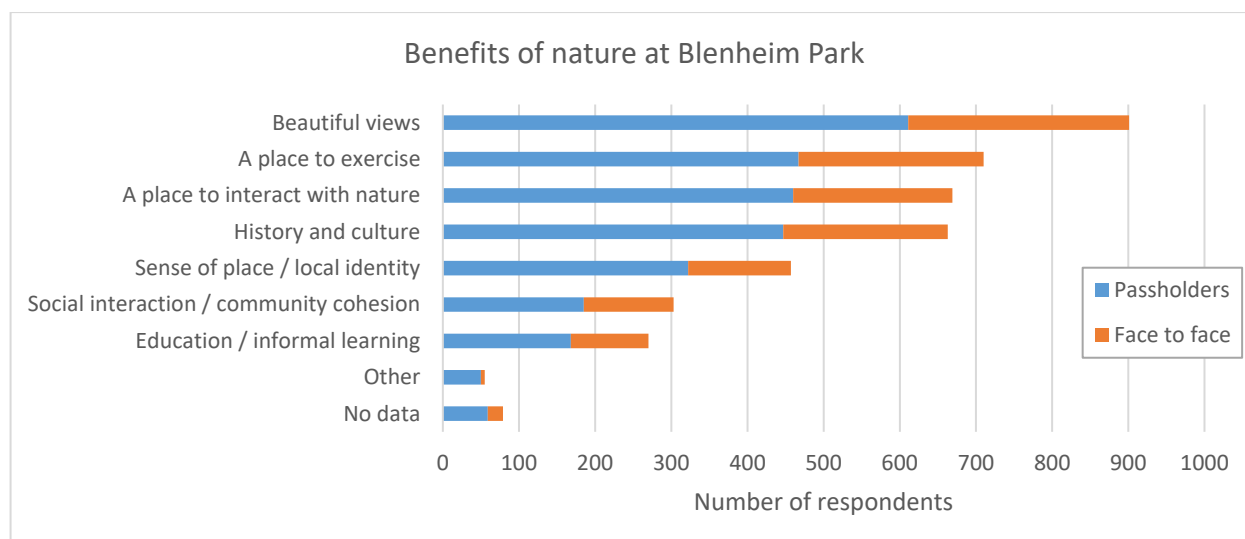
Examples of 'favourite places' (see Annex 2 for many more):

By the lake, beyond the 'Harry Potter' tree. Its very tranquil, a beautiful view, I feel like I'm in a special place when there (*Female pass holder, 45-59, visits two or three times a week, 15 minutes by foot*).

View across lake by Town Gate; bluebell woods by Coombe gate; special hill by Bladon Lodge, where there are lovely red trees (copper beeches), lovely views, the children go sledging in winter. (*Female, 35-44, visits more than once a week, 3 minutes by foot*).

Figure 32 summarises the wide range of benefits that visitors feel they receive from visiting the Park. Beautiful views were mentioned by 80% of respondents, followed by a place to exercise (63%), interact with nature (59%) and experience history and culture (59%).

Figure 32. Benefits of nature at Blenheim



People feel that the park contributes to both physical and mental health: Annex 2 contains many quotes to illustrate this, a few of which are given below. Often, people link the health benefits to specific qualities of the Park including the beauty of the landscape, the opportunity for social interactions, clean air, closeness to nature and observing wildlife. These in turn link to the other cultural ecosystem services which are discussed in the following sections.

Fresh air, enjoying the beauty of the surroundings, a chance to meet with friends and family, a chance to relax and regroup, mental wellness. *(Female pass holder, 35-44, visits two or three times a week, 30 minutes by foot).*

It always feels like I've been somewhere special, I can't afford to go away but coming here feels like I've done something or been somewhere amazing. The water the trees the gardens are good for my mental health and well being. *(Female pass holder, 45-59, visits once a week, 10-15 minutes by car).*

Health from walking at least 15000 steps. Fresh air with less pollution than elsewhere. Watching the change in the seasons bird, animal, plant and tree life. Also interesting to watch how the upkeep of the grounds progresses and the change in use of space in the grounds. *(Male pass holder, 60+, visits once every two weeks).*

Particular aspects of Blenheim Park that seem to contribute to its value as a place for recreation include:

- The size of the park and its open spaces, with freedom to wander around and choose from a wide variety of walks, and to seek solitude;
- The clean air, quietness, and relatively safe roads and paths with little traffic;
- The paved roads that make walking easy all year round for those with buggies, wheelchairs or the less mobile, or just those who don't like getting feet (and dogs) wet and muddy;
- The availability of the café and toilets, especially for those with children, or those who like to meet for a 'social coffee' after their walk with friends or family;
- The wide range of activities for children (train, maze, playground);
- The sense of heritage, and historical interest;
- The friendliness of staff and other visitors, enabling social interactions; and
- The beautiful views and chance of seeing wildlife.

5.9.1.2 Estimates of visit numbers and welfare value according to the ORVal model

We have estimated the monetary value of recreational visits to the Park and also the footpaths across the wider Estate using the ORVal model, a freely available online model developed by the University of Exeter.⁴⁴ ORVal is based on statistical analysis of the Monitor of Engagement with the Natural Environment (MENE) dataset⁴⁵, which is an ongoing survey of the visits made to green spaces by members of the public in England. The ORVal model estimates the number of visits per year to publically accessible green spaces and sections of the footpath network based on the land use, designations and points of interest such as playgrounds, viewpoints and historic features. It then assigns a 'welfare value' based on the estimated number of visits multiplied by estimated visitor expenditure in terms of travel time and travel fuel costs.

For the Blenheim Estate, we selected all the open areas and footpaths on the interactive web map that intersected any part of the Estate, and downloaded the values for each area and path segment. Because many of the footpath segments in ORVal crossed the Estate boundaries, we then scaled the footpath values according to the actual length of each path that was within the estate boundaries. This resulted in the estimates shown in Table 24, with almost 2 million visits per year and an estimated welfare value of around £5.5 million per year, of which around £4.7 million is due to visits to the Park. This is a generic estimate based on the expected visitor numbers to a green space in that location given the land cover, designations, and points of interest, rather than being specific to Blenheim. ORVal does not include visits that involve staying away from home overnight, and does not identify all the footpaths on the Estate, so those factors could lead to underestimates of the actual value.

Table 24. Estimated number of recreational day trip visits to parks and paths on the Blenheim Estate, and associated welfare value, according to the ORVal model

	Area (ha)	Length(km)	Estimated visitor numbers per year	Welfare value £/year
Blenheim Park	930.53		1,586,198	£4,715,320
Other parks, woods etc	127.23		137,955	£461,673
Footpaths on the Estate outside Park		28.68	261,314	£341,217
Total			1,985,468	£5,518,210

For comparison, 920,491 paying visitors to the Palace and Park were recorded from April 2018 to March 2019³³. Although this number is lower than the ORVal estimate of around 1,590,000 visitors, it does not account for visitors who enter on foot to use the public footpaths without paying the admission fee. A visitor survey found that the average expenditure on travel to and from the Park was £18.³³ Using this travel expenditure as a proxy for welfare value in the same way as in ORVal would result in a much higher estimate of around £18 million rather than £5.5 million, even without including the value of the time taken to travel. However it is not clear what portion of this expenditure should be attributed to the attraction of the Palace and other manmade features of the Park, and what proportion is derived from the landscape and natural features. The ORVal model is designed to estimate visitor numbers based on land cover (plus designations), so it may be able to partly filter out the impact of the natural spaces rather than the Palace.

5.9.1.3 Estimates of recreational value from the public survey

We have carried out an approximate valuation of the recreational benefits using the same approach as the ORVal model (see Annex 2). We used data on the travel time, transport mode and number of trips per year to estimate the 'welfare value' of the Park in terms of the fuel cost for journeys by car and the travel time. This resulted in an estimated welfare value of **£179,193 per year** to the 1106 respondents who provided valid travel data: an average value of £196 per person and **£4.64 per trip**. If scaled up to the 920,491 recorded visitors in 2018, this value per trip equates to a welfare value of **£4.3 million / year** for the recreational services provided by the park. This method involves several crude assumptions which introduce considerable uncertainty into these estimates (see Appendix 2 of Annex 2). However, the value is quite similar to the estimate using the ORVal tool of £4.7 million per year (see above).

5.9.1.4 *Estimating the value of the health benefits from using the Park for exercise*

Visiting the park for exercise is likely to bring considerable benefits for physical and mental health and wellbeing. The method described above estimates the value of the perceived benefits of visiting the park to the beneficiaries (the people choosing to visit), using the travel costs as a proxy for the amount that people are willing to invest in travelling to the park rather than going somewhere else. It is assumed that people factor in these health and wellbeing benefits when choosing whether to visit the park. However there will also be wider benefits to society from reduced healthcare costs and reduced absenteeism from work, which are not accounted for in the travel cost model. We have used the method of White et al (2016) to estimate these health benefits as being approximately **£393,000 / year** for the 270 survey respondents who visited the park for moderate to vigorous exercise at least once a week (see Annex 2, Appendix 2). Between 132 and 174 of these people (depending on the proportion of 'maybe's who are counted) thought they would not get the same amount of exercise somewhere else if the park was not available. Including only these people gives a more conservative estimate of **£196,000/year to £257,000/year**.

If the actual total number of regular visitors using the park at least once a week was known, this figure could be scaled up accordingly. However, it is likely that only a small proportion of the 900,000 annual recorded visitors visit the park at least once a week for exercise, and many of the most regular visitors probably responded to the online pass holder and face to face surveys.

5.9.2 *Natural beauty, landscape value and tranquillity*

The Park itself is famed for 'the most beautiful view in England', from the end of the lake towards the bridge. Beyond the Park, the western part of the estate is in the Cotswolds Area of Outstanding Natural Beauty and the land to the south of the park lies within the Oxford Green Belt, and is therefore important for providing an open landscape character to separate Oxford from the surrounding villages.

The National and Local Landscape Character Assessments are set out in the WHS management plan.¹⁷ Most of the Park is in the Cotswolds National Character Area, with a small part near Bladon being in the Upper Thames Vale National Character Area. The Cotswolds is part of the oolite Jurassic limestone belt that runs from the Dorset coast to Lincolnshire. Blenheim Park is at the bottom of the dip-slope of the Cotswold escarpment, where the hills level out into the Thames Valley. This is a gently sloping area divided by the deep winding valley of the River Glyme. The surrounding landscape is mainly the open limestone wolds – described as a rolling landscape of large, intensively farmed arable fields with a rectilinear pattern of dry stone walls and low, species poor hedgerows with few field boundary trees, though to the east of the park the landscape is semi-enclosed with a mixed land use pattern defined by a strong structure of hedgerows, trees and small woodlands. There are a number of other parklands and estate landscapes as well as Blenheim Palace, including Rousham, Ditchley, Hidcote, Kiftsgate and Stanway Chastleton.

South of Bladon the semi-enclosed limestone wolds landscape rises gently up to the woodlands on Bladon Heath and Burleigh Wood which crown the low lying hills. To the south and south west of the Park the River Evenlode winds through flat, floodplain meadows and pastures which are sub-divided by drainage ditches and fences, and the valley sides rise up towards Long Hanborough. In the open limestone wolds to the west, there is an open, expansive area of large arable fields between Gorrel Doors and Stonesfield, but around the village of Combe the landform is more folded with small woods and copses. North of the park is well-managed estate farmland with extensive woodlands, plantations and copses, and lines of oaks along roads and some field boundaries.

Local Landscape Character Assessments include the Cotswolds AONB Landscape Character Assessment; the Oxfordshire Wildlife and Landscape Study (OWLS), the Historic Landscape Assessment for Oxfordshire and the West Oxfordshire District Council landscape character assessment. Blenheim Park is in the Eastern Parklands and Valleys Character Area, an area of rolling limestone landscape which is heavily dissected by the valleys of the Glyme, Dorn and Cherwell. The underlying geology is reflected in the vegetation cover. Intensive arable farming is supported on the light, loamy soils derived from the limestone, while woodland and pasture occur

on the heavier soils of the Oxford Clay or in the wetter valley bottoms, though this natural pattern of vegetation cover has been masked by the parks, gardens and estate landscapes.

We have mapped the aesthetic value of the habitats on the Estate using the scoring approach (Figure 33). This approach scores individual habitats based on literature evidence and other sources that show that, for example, most people find woodlands, water, and biodiverse semi-natural habitats such as species-rich grassland attractive. The large number of ancient trees and the hedge network are also likely to have a high aesthetic value. However this scoring approach does not take account of beauty at the landscape level, as the scores are assigned only to the individual habitat types and features.

The public survey of Park users showed that 80% of the 1096 respondents identified the natural beauty of the Park as a benefit. The qualitative responses to the survey often linked the beautiful scenery to feelings of calmness, relaxation and inspiration, with benefits for mood and well-being (see Annex 2).

The beautiful scenery of lakes and trees is good for the soul and our health. (Female pass holder, 60+, visits once a week, 20 minutes by car).

Fresh air, really pretty and the colours and seasons. Scenery and being by water, all unspoilt landscapes (Female, 45-59, visits once a year).

The UK Natural Capital Accounts provide a monetary valuation of aesthetic value based on the uplift in house prices. For areas within 500m of a publically accessible green or blue space, the average uplift in property prices is £2,850 / year. The effect increases depending on the size of the space. As the openly accessible area around the Blenheim Lake and monument alone is around 66 ha, Blenheim Park would fall into the highest size category. This could be used to estimate a monetary value, by calculating the number of houses within 500m of the Park (taking account of the entrance points) in future updates of this assessment.

The iTree-Eco model assessed the structural value (replacement cost) of the 1070 ancient and veteran trees on the Estate as being £4.74 million. This value is strongly influenced by the data on crown completeness. For comparison, we repeated the assessment using only the default assumption of 85% completeness (i.e. 15% dead wood in crown), and this showed an estimate of £6.57 million. In reality of course, it would take many hundreds of years to replace these trees, so it is questionable how relevant this valuation is.

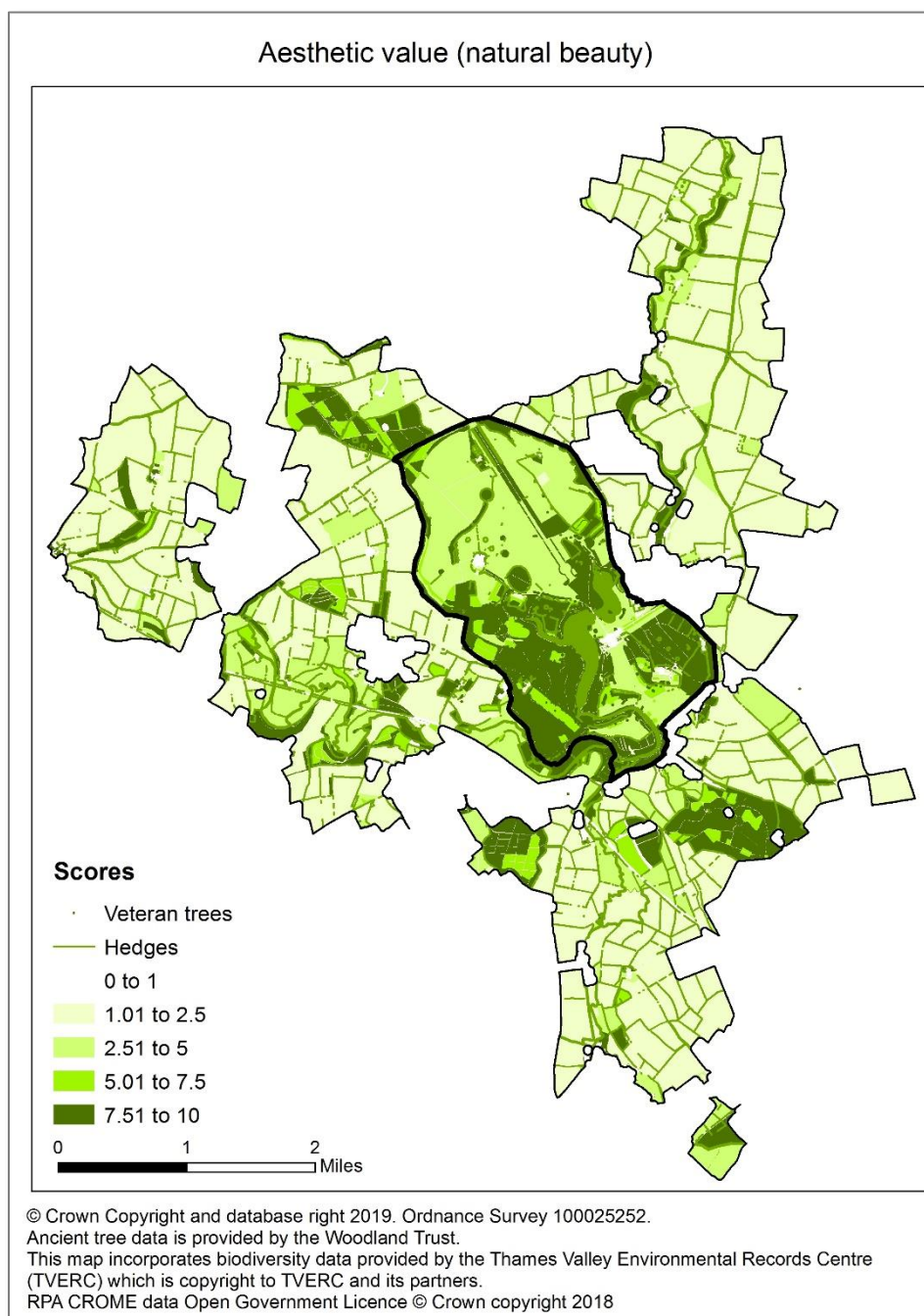


Figure 33. Aesthetic value (natural beauty) of landscape and habitats

5.9.3 Education and learning about nature

The Estate supports education about nature both through formal activities and through providing a place for informal learning. It also allows access for ecological research, including by entomologists and veteran tree experts.¹⁵

There are five regular Forest Schools and two regular forest education sessions, involving four local primary schools, one pre-school, one nursery, and a charity (the Combe Mill Society). These groups use the woodland blocks outside the Park, including Pinsley Wood, Peagle Wood, Mill Wood, Stockey Bottom Wood and Hardwick Belt Wood. These woods are also used by Scouts and Beavers. In addition, there is a drop-in forest school in the Park, close to Blenheim Lakes. Sylva, a forestry organisation, also works with the Estate to develop educational activities around forest and woodland management.

Interviews with three of the forest school leaders revealed that they are extremely pleased with the support that they get from the Estate, and that the children and staff value the Forest Schools very highly. Forest schools provide a unique learning opportunity as they are child-led, typically in small groups of around 15

children with three members of staff. One leader involved with three different forest schools described the wide range of activities that children are able to do on the Estate.

Activities vary hugely from making rope swings, dens, obstacle courses, nature treasure hunts, whittling, cooking over the fire, fire-lighting, foraging, pond dipping, nature observation activities, bug hunting, and many others, all depending on what the children ask for, or what I suggest as a spring board for them to then develop their own ideas. *(Email from Forest School Leader 2, 6 April 2020)*

Children usually spend half a day in the woods, whatever the weather, and activities change with the seasons. This could include looking at hibernation in the autumn, looking at nesting birds or hunting for frogspawn in the spring, or identifying trees as leaves emerge in summer. They can also learn about woodland management such as coppicing. There are cross-curriculum links with art, poetry and history, for example, as children write about their experiences when they are back in the classroom.

I often hear children role playing situations that they've learned about in class, their rope swing becomes a rocket to space and they can "see the planets" over the hedge, their den becomes an air raid shelter when studying the second World War, and we cooked some rationing recipes on the campfire. When we chop logs, we talk about what we're doing, "we're cutting them in half, quarters, shall we try and cut eighths?" *(Email from Forest School Leader 2, 6 April 2020)*

Another leader has been involved in forest education on the Estate since it was first allowed in 2010. The Estate allowed them to access Mill Wood via a bridge that was previously closed, so that they could use the wood, meadow and pond as part of their educational activities at the nearby Coombe Mill. Their activities have expanded to include forest schools, scouts, outdoor learning for both primary and secondary school ages, and activities for both young and old members of the public. These included opportunities for GCSE students to do fieldwork, often based around the river at Combe Mill, and for trainee teachers to do PGCE training for supervising fieldwork trips. These are more structured than forest schools, and typically involve a one-off visit where a class might learn about specific topics such as the life cycle of animals, the structure of flowers, or how species are adapted to different habitats.

Based on information for three of the forest schools and estimates of typical class sizes, visit lengths and frequencies for the others, we estimate that the seven regular forest education sessions could provide over 18,000 student-hours of educational time per year (Table 25). In addition, the GCSE fieldwork sessions typically involve a class of 30 children and ten different schools might visit during the year, bringing the total to almost 20,000. We do not have estimates for the PGCE training and other educational activities.

Table 25. Estimated number of hours provided by forest education activities on the Blenheim Estate

	Number of students	Hours per visit	Visits per week	Student-hours / week	Weeks per year	Student hours /year
Primary school 1	30	2.5	2	150	24	3600
Primary school 2	15	3	1	45	39	1755
Pre-school	15	3	2	90	39	3510
Primary school 3	14	2.5	2	70	39	2730
Nursery	15	3	2	90	39	3510
Charity	15	2.5	1	37.5	39	1462.5
Primary school 4	15	3	1	45	39	1755
Total regular sessions				0		18322.5
GCSE fieldwork	30	5	1	150	10	1500
Total						19822.5

Forest School leaders list a wide range of benefits, including education, health and wellbeing, a sense of community, problem-solving, working in teams, and encouraging children to look after their local environment. The opportunity for free play is reported to be a key benefit with long term impacts on individual development.

Leaders report that children's behaviour and motivation improves, and that these social benefits persist when children are back in the classroom. One leader said that parents benefit as well, as they are always asking questions about the Estate, and learning about the reasons for different management activities such as why trees are being felled.

Free play is a huge and essential part of children's development, something that is often lacking in many children's lives. Without the opportunity to develop through free play, not only are children missing out on a huge part of their development which has serious implications for risk taking/aversion, self confidence, problem solving, independence, self-calming, self-regulation, etc. later on, but they are also missing an essential nature connection. If they don't know what is in their back garden, park or county, they won't be inclined to protect it.

Teachers and students are under ever increasing pressure to meet standards, play time is reduced, green spaces sold off, and children are not able to get out as much or as far as they should be able to. Physically, they need to move to develop their brains, not just their fitness, to de-stress, to let off steam.

A lot of children just don't get the opportunity to talk one to one with adults or in small groups, time to just "be", "explore", or don't receive the attention that they really need and crave to develop, and FS can give children who are struggling in this way the time and space to work things out. (Email from Forest School Leader 2, 6 April 2020)

The success of the wide range of educational initiatives was attributed to the positive and helpful attitude of the Estate staff, who are *"willing to let you try things, and work in partnership"*. As well as allowing access, staff also provide practical help such as providing log seats and opening up overgrown paths, and support with ensuring health and safety.

I have always thought Blenheim does a brilliant job supporting access to their estate and they should get more acknowledgement for it! As a local resident I also have seen the benefits of the estate to local communities. (Email from Forest School Leader 1, 2 April 2020).

The environment is an inspiration for learning and Blenheim have always been more than accommodating re allowing us to use their site. We are very grateful. A phrase we often hear is 'this has been the best day at school'. (Email from Forest School Leader 3, 14 April 2020).

Forest school leaders had few suggestions for how their experiences could be improved; the main request was for the currently level of support and access to continue as it was felt to be working very well. There could be opportunities to get secondary schools more involved in fieldwork, though this would require a source of funding to purchase equipment such as binoculars, tape measures and survey equipment. The main constraint is finding enough trained staff, parents or other volunteers to help supervise the schools.

In addition to the organised educational activities and scientific research, further opportunities arise through informal use of the Park and Estate by visitors. These opportunities are being expanded by the creation of permissive paths and forest trails in Mill Wood and Pinsey Wood near Hanborough. In addition, the Estate allows visits by groups for activities such as bat and otter spotting or tree tours.

Blenheim Park in particular provides good potential for visitors to learn about nature, with its wide range of high value semi-natural habitats and rare species such as bats, birds, plants, reptiles and fungi. In the public survey, 24% of respondents identified 'learning about nature' as a benefit of visiting the Park, but several of them thought that more could be done through information and signage to help visitors find out more about the trees, archaeology and other features. This is supported by the comment in the Park Management Plan that *"Site interpretation within the park is generally low key. Interpretation of the park could be significantly enhanced in some locations, such as key features like Rosamund's Well or the Column of Victory, both through the range and depth of information supplied and through the use of modern computer based technology"*.¹⁵

Signs should say how long it will take to walk around. The trees are old and they are fascinating, would be good to have some signs on them too - my grandchildren will love information like that (*Female, 60+, first visit, 25 minutes by car*).

The economic assessment by Oxford Brookes states that the imputed value of educational visits and guided tours provided by Blenheim to schools and other educational institutions is estimated at £279,000; while complimentary passes worth £228,374 (+844%) were donated. However, it is likely that many of these tours and visits were to the indoor areas of the Palace and it is not known to what extent they addressed the natural parts of the Estate.

5.9.4 Interaction with nature

The public survey revealed that 59% of respondents valued Blenheim Park as a place to interact with nature. Their comments often linked experiences of nature to benefits for well-being (Annex 2).

I enjoy the open space and the beauty of the flowers, trees and shrubs in the different seasons. I feel very close to nature. (*Female pass holder, 45-59, visits once a year*).

I relax when surrounded by nature - especially woodland (*Female pass holder, 45-59, visits once a month, 25 minutes by car*).

Opportunities to interact with nature depend mainly on the quality of the semi-natural habitats, the abundance and diversity of species and the accessibility of the grounds. The delivery of this service will therefore depend strongly on the quality of the assets supporting biodiversity (see section 4.5). However there can also be conflicts between public accessibility and wild species, e.g. disturbance of nesting birds or small mammals by dogs, which may need management.

The scores for 'Interaction with nature' are mapped in Figure 34.

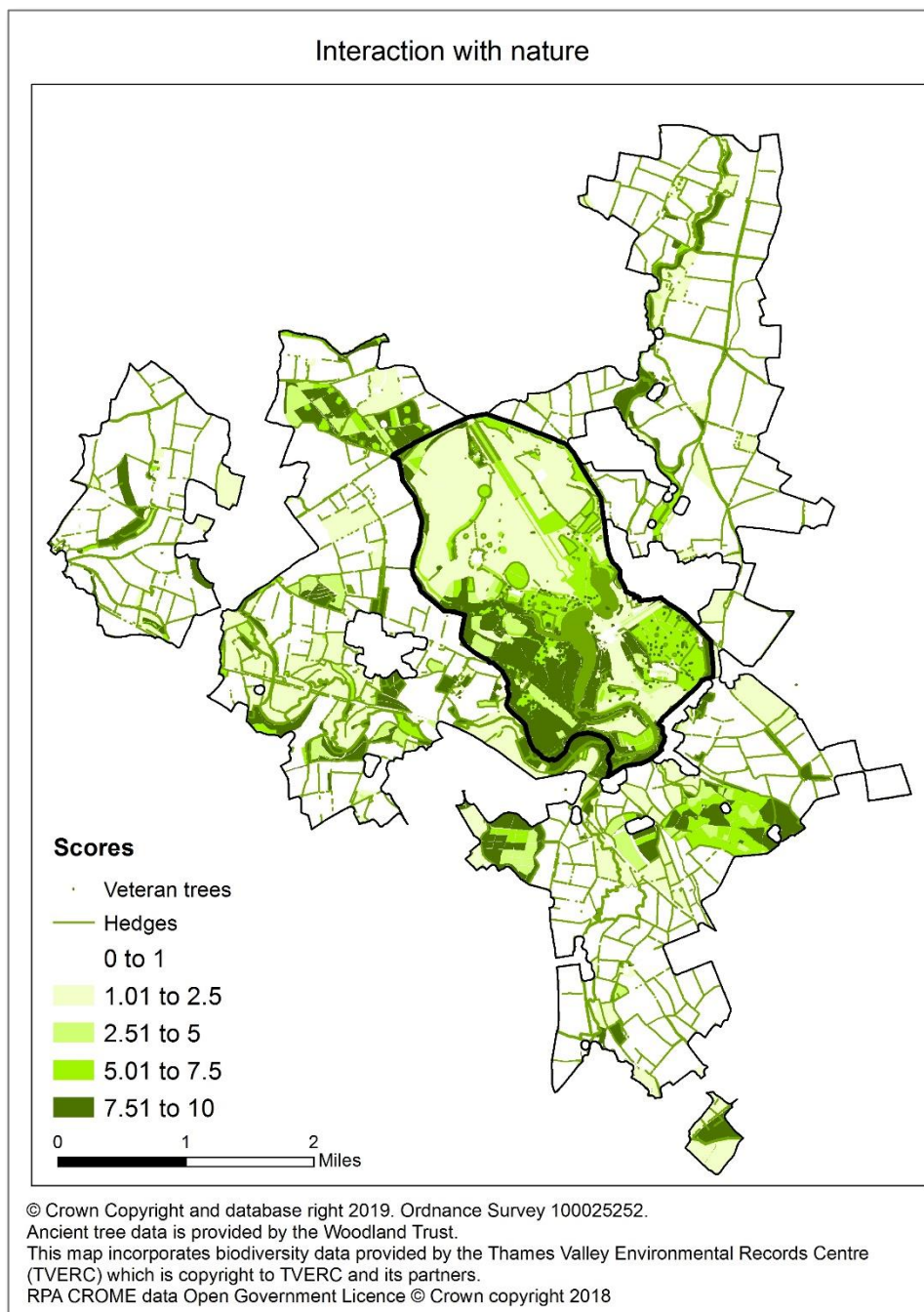


Figure 34. Interaction with nature at Blenheim

5.9.5 Sense of place and cultural heritage

Blenheim Park is exceptionally important in terms of historic and cultural value. It was inscribed as a World Heritage Site in 1987 both for the architectural importance of the Palace and for the landscaping designed by Lancelot 'Capability' Brown⁴⁶, and it is also a Grade 1 site on the Historic England Register of Parks and Gardens of Special Historic Interest in England.

The Park was created from the medieval royal hunting park of Woodstock, probably first enclosed by Henry I at the beginning of the 12th century, and later occupied by many monarchs who developed the buildings and surrounding gardens⁴⁷. The current Palace, built between 1705 and 1722, represented the beginning of a new style of architecture, and was set within a great formal garden designed by Henry Wise, Queen Anne's Royal Gardener. A formal canal scheme was implemented along the course of the River Glyme, and then Lancelot Brown was called in in 1764 to landscape the central core of the park, flooding the river valley to produce the

two lakes, and landscaping the surrounds, with new belt plantings around the park boundary. The lakes are seen as one of the greatest examples of naturalistic landscape design, and the Palace and Park were considered to have exerted a great influence on the English Romantic movement, characterised by its love of nature. Restoration and replanting have continued since then, including the creation of the formal gardens to the west and east of the house in 1908-30 by Achille Duchene.

The surrounding landscape also has a rich history of national, regional and local significance with many Scheduled Monuments. The field patterns largely reflect both the medieval open field system, with fossilized areas of ridge and furrow, and later planned enclosure landscapes. According to the WHS management plan, the site of the former royal palace north east of the Grand Bridge, the Akeman Street roman road and the park walls are all considered to be of national importance.¹⁷ Sites of archaeological value were shown on Figure 16 in Section 4.5, and include:

- An 80m section of Grim's Ditch south west of the Ditchley Gate;
- Sections of the Oxfordshire Grim's Ditch and a section of Akeman Street Roman road immediately south of North Lodge;
- A bowl barrow 350m south west of Furze Platt Farm;
- Ten medieval pillow mounds and part of an associated enclosure 300m north west of Combe Lodge;
- A possible Romano-British earthwork 300m south west of Rosamund's Well.

The ancient and veteran trees play an important role in the sense of place experienced at Blenheim, and the inclusion of four of the largest trees in the Monumental Trees citizen science dataset¹² supports this. Some of the ancient, stag-headed oak pollards of the park may be direct lineal descendants of those recorded in the Domesday Book¹⁸.

In the public survey, 41% of people identified sense of place as a benefit, and 59% identified history and culture as a benefit (see Annex 2). As well as the links to Capability Brown and Churchill, respondents often mentioned the ancient oak trees, a personal sense of belonging to a 'special place', emotional attachment and memories, or a sense of pride and local identity.

He walks here because he feels that it's special to him and a great place to be. (Male, 35-44, visits once a week, 15 minutes by foot).

It's a much valued local treasure which we are lucky to have (Female 60+, pass holder, visits every couple of weeks, lives a ten minute drive away)

Makes them feel "proud to be British," reminds them of history, Churchill. (Mixed group, 60+, visits once a year).

The scores for 'Sense of place' are mapped in Figure 35. This shows only the value of the natural habitats at Blenheim for sense of place, not the built elements such as the Palace and Bridge, although these built elements do play an important role in the overall experience of visitors. The habitats that form part of designated sites receive a higher score, with an uplift ranging from 10% for sites with one cultural or nature designation to 15% for those with two or 20% for those with three or more. Scheduled ancient monuments receive a minimum score of 7 unless they are arable land, as arable cultivation typically damages historic sites. However these score differences are not always visible within the five broad bands of scores shown on the map.

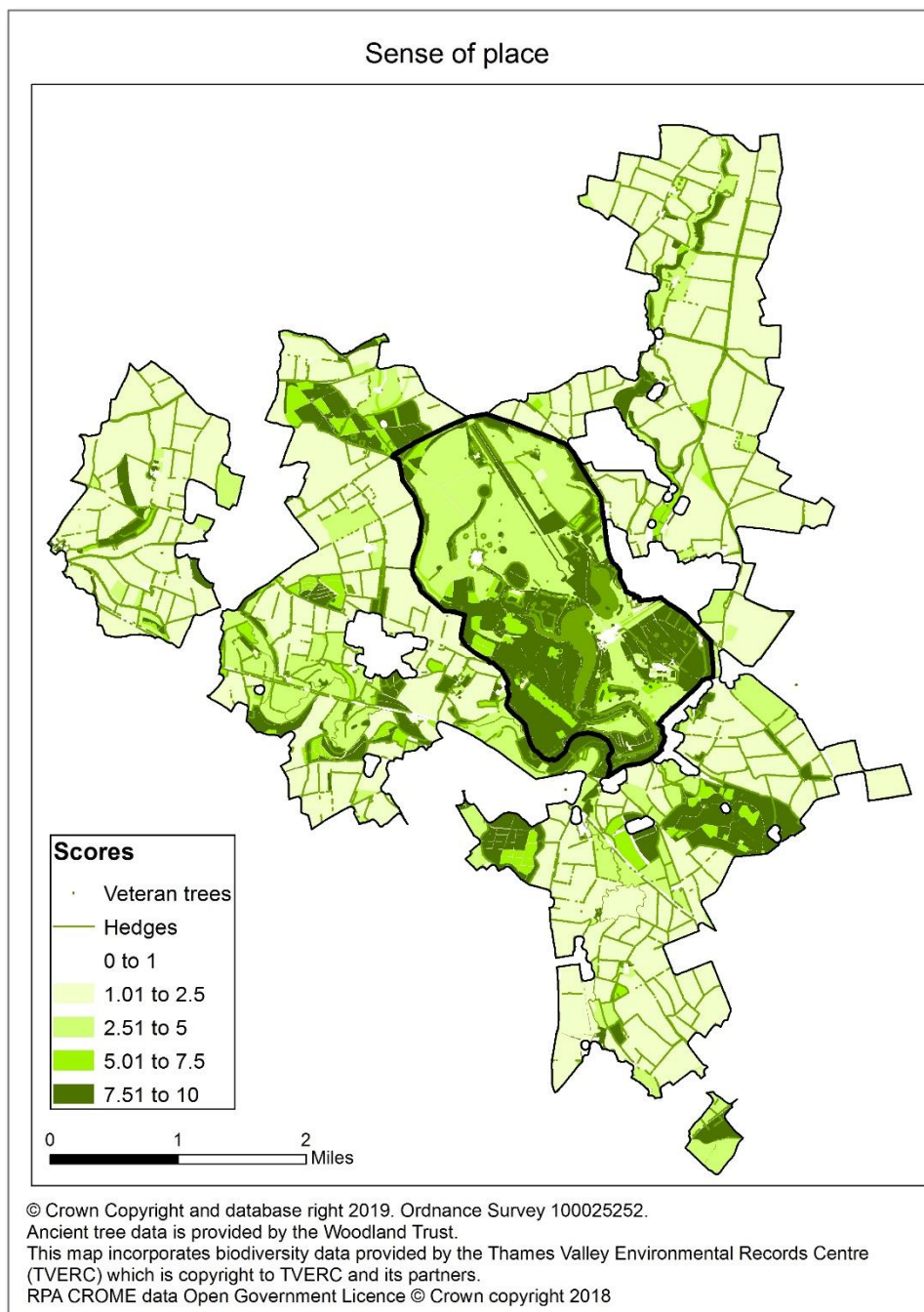


Figure 35. Sense of place provided by natural habitats at Blenheim

5.10 Overview map

To provide an overview of the natural capital value of the Estate, Figure 36 shows the maximum value from all the regulating and cultural ecosystem services, with the high scoring areas for food production overlaid in orange. This highlights the value of the woodlands, the parkland with scattered trees in the Park, and the semi-natural grasslands along the river valleys, which all score highly for at least one of the cultural and regulating services (dark green), while the small patches of Grade 2 arable land that score highly for food provision can be seen in the south-east in orange.

The maximum value is chosen to provide this overview because the scores for different services cannot be added together or averaged, as they are measuring different things. For example a score of five out of 10 for carbon storage is not necessarily equivalent to a score of five out of 10 for pollination or recreation, in terms of the value to people. The scores indicate the extent to which the land delivers the maximum possible supply of each service, but they are not biophysical values in common units and so cannot be added together.

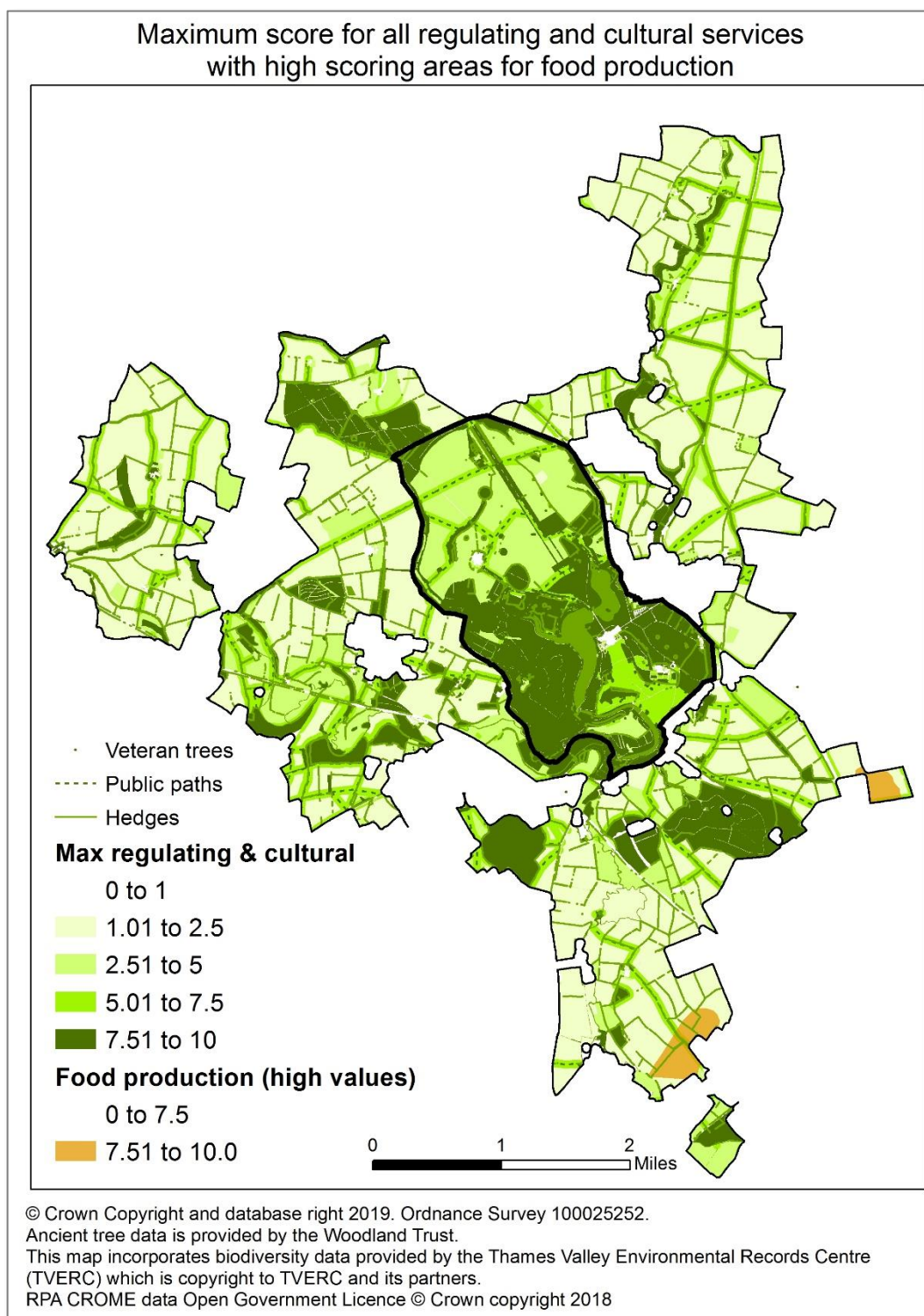


Figure 36. Maximum score for all regulating and cultural services, and high scoring areas for food provision

When viewed in the context of the local area, it is noticeable that although the Park provides very high levels of regulating and cultural ecosystem services, the wider Estate outside the Park appears to have larger areas of low-scoring land than the surrounding area (Figure 37). This is a consequence of the large arable fields and the lack of high grade agricultural land. In contrast, the surrounding area appears to have a more diverse patchwork of arable and grassland, with smaller fields and more hedgerows.

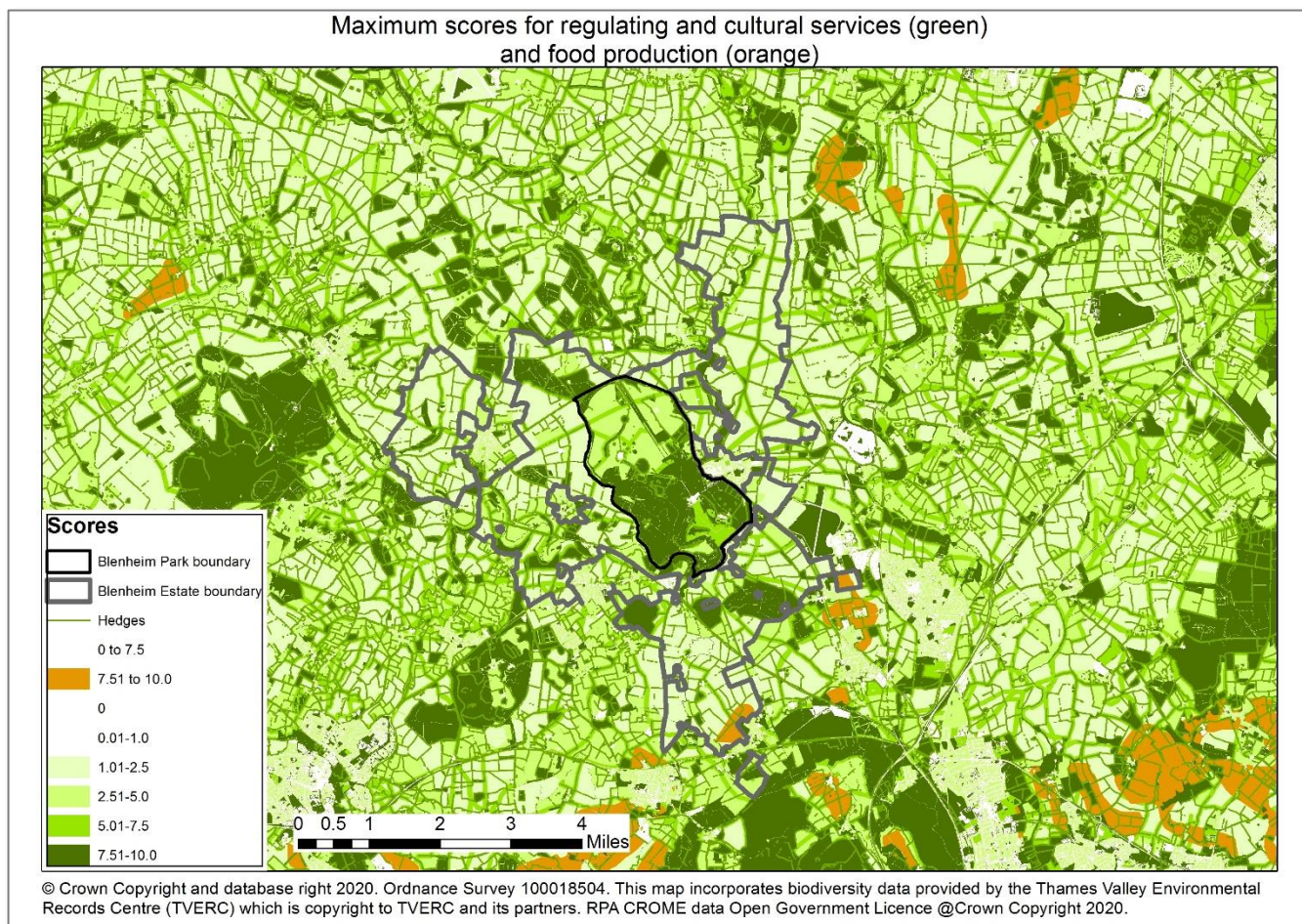


Figure 37. Maximum scores for regulating and cultural services (green) and high-scoring areas for food production (orange) for the Blenheim Estate in the context of the surrounding area

6 Threats and opportunities

This report demonstrates that there are significant natural capital assets at Blenheim, including the beautiful and historic landscape of the Park, the hundreds of ancient and veteran trees, and the fragments of semi-natural grassland in the river valleys. However there are also large parts of the Estate that are dominated by intensive arable cultivation. After discussion with the Estate team and others working on natural capital-related projects at Blenheim, we have compiled a short list of potential threats to natural capital and opportunities for improvement. This also draws on suggestions in the UNESCO WHS Management Plan for the Park¹⁷. This is a preliminary list of suggestions and much more detailed analysis is required to expand and refine these ideas.

6.1 Potential threats to natural capital

Possible future threats include:

- Soil erosion from arable cultivation on sloping land, and associated siltation and water quality impacts in the Blenheim Lakes and downstream watercourses. This could be exacerbated by future climate change and an associated increase in extreme weather such as heavy rainfall events.
- Poor water quality in the River Glyme and the Blenheim Lakes due to phosphates discharged into the Glyme from Woodstock Sewage Treatment Works, as identified by the BSG Ecology study.¹⁶
- Future spread of animal and plant diseases, exacerbated by climate change, threatening local biodiversity, livestock health, food crop and forestry production. Acute Oak Decline is already affecting trees in the Park.
- Spread of invasive species could also affect biodiversity, including in the freshwater habitats.
- Higher temperatures and prolonged droughts due to climate change could affect crops and biodiversity, e.g. threats to survival of the ancient trees in the Park.

- Fluctuations in food markets could affect the economic viability of agriculture on the Estate.
- Loss and damage to historic and archaeological sites; several archaeological assets are on the Heritage at Risk register due to threats from arable ploughing.
- Loss of species-rich grassland to ploughing or afforestation.

6.2 Potential opportunities to enhance natural capital

The natural capital maps generally reveal that the woodlands, semi-natural grasslands and parkland areas of the Estate, especially in the Park, offer high levels of many cultural and regulating services, while the rest of the Estate is mainly mid-grade arable land that produces food but offers few other services.

The threats listed above suggest that there could be opportunities to enhance natural capital assets in order to address the local problems of soil erosion and water quality, while also seeking to address the global climate and biodiversity crises by storing and sequestering more carbon and providing habitat to support pollinators and other wildlife. Flood protection is also a priority option under the Countryside Stewardship scheme in this catchment, i.e. the Thames catchment upstream of Oxford.^{39,40} Applicants are encouraged to consider measures that:

- reduce the amount and rate of surface water run-off
- reduce soil erosion
- slow the movement of floodwaters on floodplains.

The Blenheim Estate's role in food production should not be neglected: if food production is reduced, it will need to be produced elsewhere in the UK or overseas, possibly with higher environmental impacts. Therefore it is best to minimise any reduction in food production, through focusing any land use change on less productive areas. Finally, there are also opportunities to further enhance the recreational, educational and other cultural opportunities that already provide significant benefits for visitors and local communities; perhaps needed more than ever in the light of the health and wellbeing issues arising from the current COVID-19 pandemic.

Opportunities that have been identified so far are listed below: they include restoring semi-natural grassland; targeted tree-planting or natural regeneration; re-wilding in the Glyme and Dorn valleys; creating wildlife corridors to link into the Oxfordshire Nature Recovery Networks; encouraging more sustainable agricultural management; and enhancing the cultural and recreational value of the Park by providing additional paths and interpretation guides. There may be opportunities to fund some of these schemes through voluntary carbon offsetting, biodiversity offsetting (planned to become mandatory for many development projects), agri-environment schemes or woodland carbon grants. This is only an initial list of suggestions, and further work would be needed to expand and refine this list in consultation with stakeholders.

6.2.1 Restoring semi-natural grassland

According to the TVERC Phase 1 habitat map, the Estate may contain some important remnants of semi-natural grassland. A total of 147 ha is mapped, including neutral grassland and marshy grassland in the river valleys, calcareous grassland in High Park (Combe Bottom and smaller patches in the woods) and on the slopes of Reed Hill SSSI, and even a small 2ha strip of rare dry acid grassland in the High Park woods. However, only 3% of the Estate is semi-natural grassland (compared to 4.4% of Oxfordshire as a whole).

The northern fields of the Park, which were reverted from arable land 10 years ago, are very heavily grazed improved grassland, with a short sward. Restoring some of this area to semi-natural species-rich calcareous grassland would provide habitat for pollinators and other species, improve the attractiveness and sense of place for visitors, and store more carbon in the soil. There could also be opportunities to improve the flower species richness in the parkland area in the south of the Park (Lower Park). This is in line with the recommendation of the UNESCO WHS management plan to “continue the extensive management of sheep grazed parkland and areas of semi-natural grassland to enhance grassland species diversity”

Targeting enhancements close to any existing remnants, such as in the Combe Bottom and Icehouse valleys, may help to encourage regeneration with colonisation of local species. However, the Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust (BBOWT) advise that it is unlikely that reducing the grazing density alone would be sufficient to restore semi-natural grassland in the northern fields, as the land was formerly arable. It would be necessary to test the soil and determine the level of nutrient enrichment in order to establish whether restoration is feasible. Active ground preparation and seeding may be necessary, as the grassland is unlikely to recover through natural regeneration due to lack of a seed bank together with probable nutrient enrichment of the soil. In order to maximise benefits, it would be preferable to use grassland establishment methods that disturb the soil as little as possible, such as preparing the ground for seeding with a tine rather than by ploughing.

Mob grazing has been proposed as a possible method for improving grassland condition. However, this will not necessarily result in species-rich grassland, according to BBOWT. If the soil is enriched in nutrients and there is no local seed bank then mob grazing may simply result in very long grass. Positive interventions would be required to achieve grassland restoration. BBOWT suggest that it could be interesting to experiment with mob grazing and monitor the biodiversity impacts.

The BSG ecology report¹⁶ recommended the introduction of buffer strips at least 10m wide around the edge of the Blenheim Lakes, to help restore favourable ecological status by trapping sediment or pollution in runoff entering the Lake, as well as avoiding the use of fertilisers, herbicides and pesticides within 500m of the lake shore. This is another opportunity to introduce wildflower-rich semi-natural grassland rather than the current short-mown amenity grassland, with the added benefit of improving aesthetic value, sense of place and opportunities for visitors to interact with nature.

Outside the Park, there are threats to semi-natural grassland in some of the Local Wildlife Sites that could also be addressed through protection and restoration. There are also large areas of arable land on the Evenlode floodplain, including an island surrounded by two arms of the river, which may offer opportunities for grassland restoration to lowland floodplain meadows. Introducing more grassland, woodland, scrub or wetland areas could help to break up the large arable fields that contrast with the surrounding patchwork of grassland and arable in the local area outside the Estate (Figure 37).

Grassland restoration should eventually result in greater soil carbon sequestration, which should in theory offer the potential for funding via voluntary carbon offsetting or agri-environment grants. The challenge is that this can be hard to monitor and verify, as most carbon funding is geared towards tree planting schemes. More research is needed into methods of verifying the carbon impacts of grassland restoration. The Trust for Oxfordshire's Environment is currently looking into setting up a carbon fund which covers not only tree-planting but also other types of habitat restoration. It could also be possible to fund grassland restoration as a biodiversity net gain project. "Establishing and enhancing low-input, herb-rich grassland" is also a Countryside Stewardship priority in the Cotswolds National Character Area, which covers the northern part of the Park and the Estate.³⁹

6.2.2 Tree planting, regeneration and woodland management

Although there is already a considerable amount of carbon stored and sequestered by the trees and woodlands in the Park, most of the wider Estate is arable or improved grassland with low levels of carbon storage. Tree planting would help to improve carbon storage and sequestration, and would also provide flood and erosion protection. However it should be targeted to avoid the few remaining areas of semi-natural grassland.

There are opportunities for woodland, scrub and hedgerow creation either through planting or natural regeneration. On the wider Estate this could be targeted at low grade farmland, especially on steep slopes or in the flood zone. Options could be aligned with the Tree Opportunity Map currently being developed for Oxfordshire by the Lord Lieutenant's office, and could include blocks of woodland, contour strips across slopes to help reduce soil erosion, silvo-arable, silvo-pasture (planting trees as shade and shelter for livestock) or woodland and hedgerow strips along field boundaries or dividing very large fields. Hedgerows, hedgerow trees and field trees are all on the list of Countryside Stewardship priorities for this area, and will add to the 'sense of

place',^{39,40} and could be targeted at splitting some of the larger arable fields into smaller units, or introducing boundaries to help with mob grazing.

In the Park, there are opportunities in the large open improved grassland areas of the northern fields but any tree planting must be planned carefully to complement the landscape and enhance biodiversity. Woodland blocks need to be above a certain size in order to provide core habitat for specialist woodland species, but if this is not appropriate for the landscape in the Park then other options include planting individual field trees to develop into open grown specimens; silvo-pasture; extending the width of the tree belts around the perimeter of the northern fields; or allowing the edge of the tree belts to develop a scrub margin to support birds and other wildlife. There is currently little scrub habitat in the Park and the shrub understorey is largely absent in the woodlands, so this last option could be beneficial to enhance landscape and habitat diversity.

The High Park SSSI woodlands are identified as being in favourable condition²¹, with plenty of fallen and standing dead wood, but surveys have shown that the ground flora and shrub understorey is sparse and there is little regeneration of saplings. The High Park Management Plan stresses the importance of conserving structural and species diversity and soil condition:

The wood decay insects that are unique to ancient wood pasture often rely not only on the decaying trees but also the nearby thorns, elders and other flowering plants. Conserving the ecological value of the veteran trees requires as much attention to maintaining a diverse surrounding habitat as to the trees themselves. There are also interactions with soil flora and fauna, not least the mycorrhizae associated with the old trees, that play a role we can only guess at. Conservation of the soil environment, for example by minimising compaction, should be regarded as of equal importance to conserving the more obvious flora and fauna. *High Park Management Plan*¹⁰

The UNESCO management plan for the Park contains specific recommendation for woodland management in the various types of habitat occurring in the Park, including wood-pasture, closed canopy oak woodland, boundary belts, and open grassland. Recommendations include:

- Maintaining the minimum intervention approach to deadwood.
- Locating successor veterans.
- Monitoring the impact of Acute Oak Decline.
- Conserving hawthorn and elder, and other species within the ground flora.
- Planting seed collected from ancient oaks in High Park to germinate and replant.
- Considering a wider range of species in the boundary belts as a response to predicted climate change.
- Protecting veteran trees in the parklands, replanting where appropriate for continuity.
- Maintaining woodland ground flora and the use of predominantly native broadleaf tree and shrub species.

Options that enhance the structural diversity of woodland vegetation, such as retaining dead wood, a shrub understorey, ground flora and areas of scrub, will benefit biodiversity by providing habitat for invertebrates including pollinators and pest predators. There is a programme of haloing around veteran trees in an attempt to prolong their life, which is a relatively new approach,¹⁰ but this has had mixed results at Blenheim.⁴⁸ It is possible that the oaks at Blenheim are more sensitive to changes in local microclimate, or to damage to the network of mycorrhizal fungi that interacts with other trees, compared to trees that have responded well to this approach elsewhere. Recent research has shown that even leafless stumps can be kept alive by water and nutrients received from surrounding trees via natural root grafts or mycorrhizal connections between their intertwined root systems.^{49,50}

Tree planting could be funded through voluntary carbon offsetting, agri-environment payments, and via the Woodland Carbon code and guarantee. Managing for biodiversity could be funded under a biodiversity net gain project.

6.2.3 Improving agricultural sustainability

The Estate team could provide incentives to encourage tenant farmers to adopt beneficial land management such as regenerative or organic agriculture that puts carbon back into the soil, or penalise land management that damages natural capital such as over-cultivation of soil or over-use of agrochemicals. This could also encourage targeted reversion of certain arable fields to grassland, for example on steeper slopes or floodplains, such as the Evenlode floodplain in the south of the Estate.

6.2.4 Rewilding the Glyme and Dorn valleys and improving water quality

Water quality in the rivers on the Estate is generally poor, and Blenheim Lake suffers from siltation and algal blooms caused partly by phosphate pollution from the Woodstock Sewage Treatment Plant. There are opportunities to address this through the creation of riparian buffer strips of semi-natural grassland, scrub or woodland along the rivers and around the Lake, as recommended by the BSG report.¹⁶

Atkins are currently developing a series of options aimed at reducing soil erosion and agricultural runoff in the Glyme valley and improving water quality in the lake.⁵¹ One option is to convert some of the arable land on the valley slopes to species rich semi-natural grassland. This could help to connect the existing fragments of unimproved neutral grassland in the Glyme and Dorn valleys into a more coherent network. Other options include conversion of arable to agroforestry; introducing more hedgerows and riparian buffer strips; adding woody debris to the river in order to encourage the river to spill over onto the floodplain water meadows; and creating a series of wetland features and pools on the water meadows to slow the water during flood events and filter out sediment and pollution while still allowing fish to pass. Restoring the water meadows in this way would be in line with the Countryside Stewardship priority for this area to “maintain and restore historic water management systems, including those associated with water meadows”.^{39,40} Alternatively, a more radical opportunity is to introduce beavers to create re-wilded wetland areas, providing natural flood management as well as improved water quality, habitat for wildlife and eco-tourism opportunities. These options are all in line with the Countryside Stewardship priorities for this area, which include “establishing new wetland habitat including wet grassland, pond complexes, fen and reedbed, within sub-catchments where they are likely to improve water quality, reduce run-off rates into watercourses, add to biodiversity and landscape character and protect historical features” as well as adding hedgerows to “manage water flow, reduce soil erosion, create wildlife habitats and corridors and strengthen the local landscape and historic field boundary patterns”.^{39,40}

The 2015 BSG report recommended introducing extensive reedbeds where the Glyme enters Blenheim Lake, and in the lake itself, to help remove pollution and sediment, ideally complemented by introduction of phosphate-stripping technology at Woodstock Sewage Treatment Plant.¹⁶ Since then, plans to dredge the lake have been made which will destroy the existing reedbeds, but new ones will be planted.²⁴

6.2.5 Linking Blenheim into the new Nature Recovery Networks for Oxfordshire

The government’s 25 Year Environment Plan specified the creation of nation-wide Nature Recovery Networks (NRNs) to help reverse biodiversity decline in the UK. Oxfordshire stakeholders, led by Wild Oxfordshire, BBOWT and TVERC, have recently produced the first version of a set of NRNs for Oxfordshire. These were created by building on the existing Conservation Target Areas, and linking them into a more connected network mainly by integrating them with the Freshwater Habitat Trust’s Important Freshwater Areas. The Blenheim Estate is located in a key position within this network, at the potential junction between six Conservation Target Areas (Figure 38, Figure 39, Figure 40). Large parts of the Estate fall within the designated Recovery zone targeted for habitat improvements or restoration. Carefully targeted habitat restoration in this zone could link up the four northern CTAs (Glyme and Dorn, Blenheim and Ditchley Parks, North Evenlode Valleys, and Wychwood and Lower Evenlode) with the Oxford Meadows and Farnmoor and Wytham Woods CTAs to the south. This pivotal position puts Blenheim in a very strong position to bid for funding from biodiversity net gain projects.

Restoration could focus on linking up existing areas of semi-natural habitats on the Estate to form connected wildlife corridors that link to the NRNs. Hedgerows and field margins could play an important role here, enabling corridors to be created across farmland while still retaining the value of the land for food production.

Other options include managing waterbodies to ensure a variety of wetland habitats associated with open water, emergent and marginal vegetation. Any new housing developments being built on Estate land could integrate networks of green and blue infrastructure such as sustainable drainage schemes, in order to create continuous habitat networks through the developments.

Figure 38. Blenheim within the Oxfordshire Nature Recovery Networks

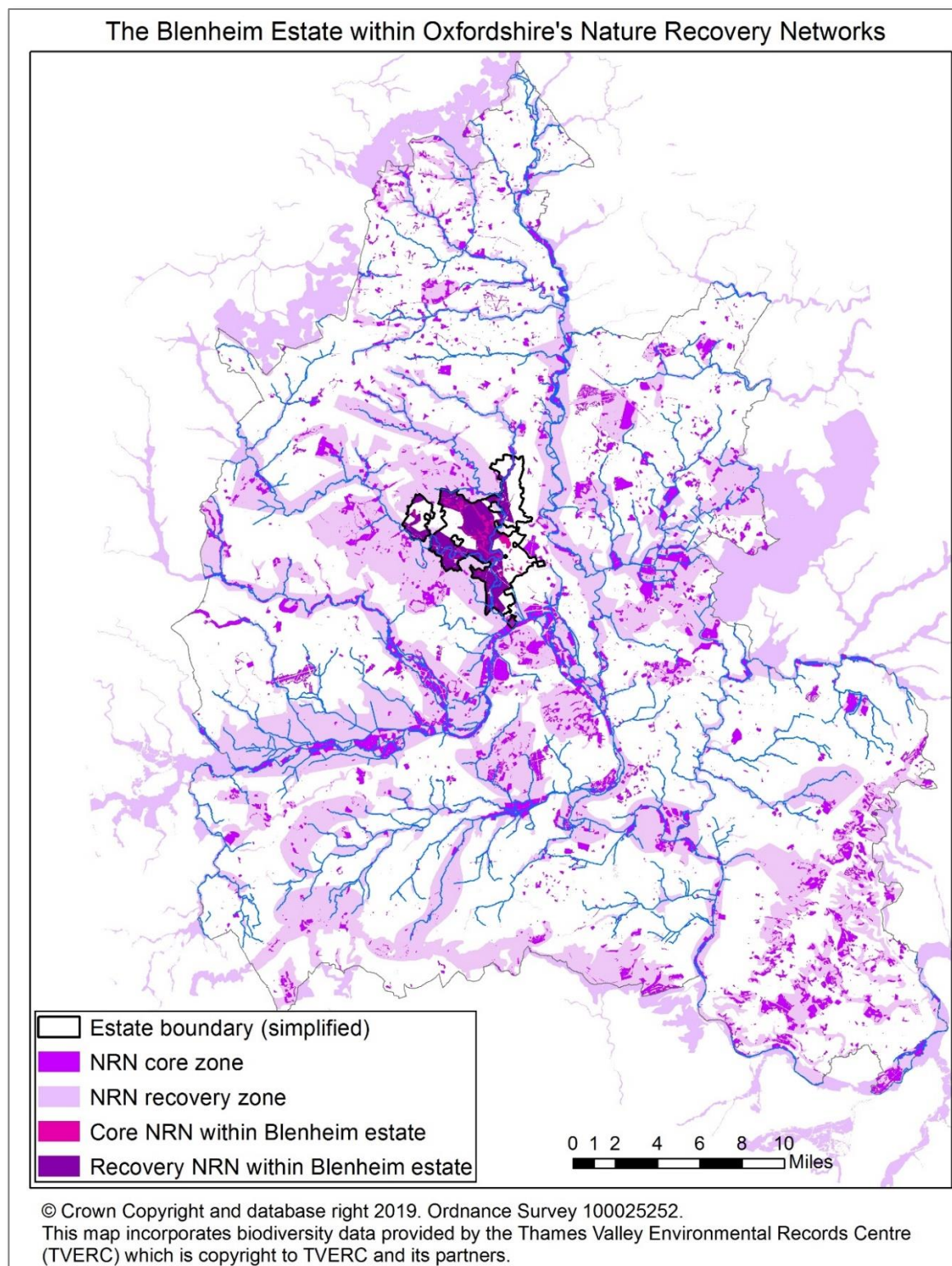


Figure 39. Nature Recovery Networks at Blenheim

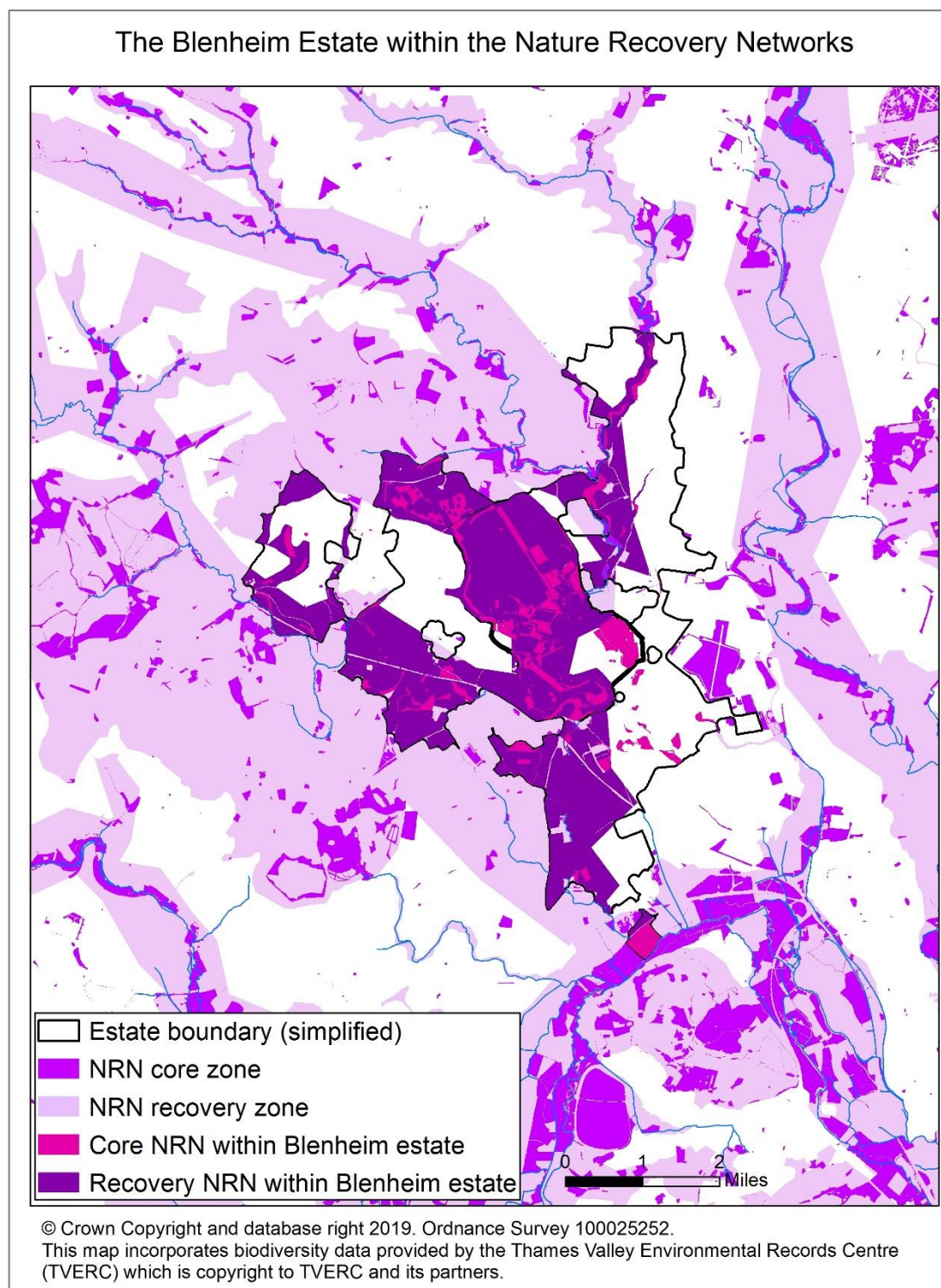
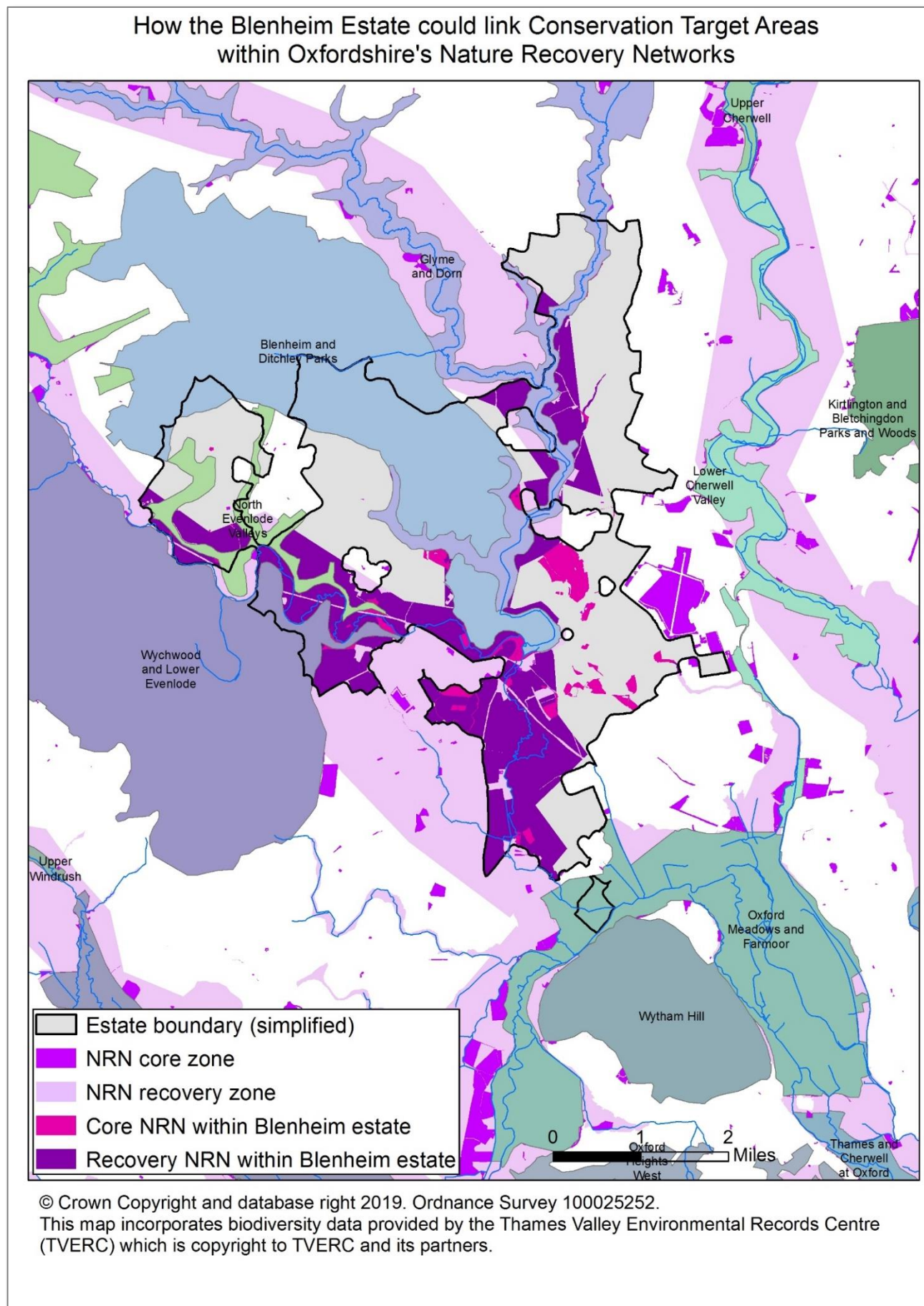


Figure 40. How Blenheim could link different Conservation Target Areas within Oxfordshire's Nature Recovery Networks



6.2.6 Enhancing cultural value

The Estate has already identified the opportunity to improve the connectivity of recreational routes, including by creating a new network of cycle routes to link the villages that surround the Estate. This would have health and well-being benefits from extra physical activity. When park users were asked about this in the public survey, many were enthusiastic but some were keen to ensure that any new cycle routes allow a good separation of cyclists and walkers.

Park users identified opportunities to improve education and learning about nature by providing more interpretation signs and signage, e.g. to highlight the archaeological features in the park, or identify the ancient trees. They also requested more benches around the lakeside walk, to help older and less mobile visitors to complete the walk around the lake, and more dog waste bins. Disabled visitors feel strongly that they should be allowed to park by the Palace again.

The WHS management plan identifies a risk of over-use of the main visitor areas, and recommends 'Looking at ways of encouraging visitors to see more of the park, through improved interpretation and education, thus also spreading the use across the whole site'.¹⁷ Extending the footpath network to provide a greater variety of circular walks of different lengths, and adding interpretation boards for Grim's Ditch and other archaeological features in the northern fields, could help to encourage more visitors into the wider Park, taking pressure off the central Lake, Palace and Gardens. Any work to implement the other suggestions for enhancing natural capital, such as rewilding or grassland restoration, could also be used as a focus for educational and recreational activities or eco-tourism either in the Park or the wider Estate.

The Heritage at Risk register identifies that some archaeological assets should be protected from further damage from ploughing by conversion to grassland or no-till cultivation.

7 Recommendations for annual updates and improvements to the methodology

This report has provided an initial snapshot of the state of natural capital at Blenheim in 2020, although the dates of the latest available data vary considerably. Some datasets are updated annually, such as the Farm accounts, while others are only updated every few years, such as the Water Framework Directive status, or not at all. Future updates may be able to refine the methodology and incorporate new data as it emerges.

The detailed technical steps needed to update the assessment annually have been listed in a separate document. Broadly, an update should include the following steps.

- Create a new base map using the latest versions of:
 - OS MasterMap, which is updated every 6 weeks
 - TVERC Phase 1 Habitat and Land Use map, updated every six months;
 - OS greenspace data, update frequency unknown;
 - RPA CROME crop data, updated every year
 - Open Street Map paths, updated regularly
- Ground-truth this map through incorporating the existing set of corrections identified during this initial assessment (if necessary), and then asking the Estate team to identify changes since the last assessment that are not reflected in the updated base map.
- Obtain any available updated data on biodiversity and water quality, from surveys.
- Check if any of the historic or nature designations have changed.

- Update the ancient and veteran tree inventory from the Estate database and the Woodland Trust, clean and check the dataset, and re-run iTree-Eco using the new data, to generate estimates of carbon stored and sequestered, pollution removed, avoided runoff and structural value.
- Use the updated habitat maps to generate an updated natural capital asset inventory and updated ecosystem service scores and maps, then change all the associated figures, tables and reported numbers in the report.
- Update the Farm Accounts and re-run the Whole Farm Income calculation.
- Obtain updated livestock numbers and locations from the Estate team and re-run the grazed biomass calculations.
- Obtain updated data on mineral water production and (if available) data on renewable energy production, to add to the report.
- Obtain updated MyForest data and re-run the estimates of potential sustainable wood extraction and carbon stored in the woodlands.
- If the estate boundaries have changed, re-run the OrVal assessment and the NatureTrade assessments.
- If desired, re-run a public survey and/or annual passholder survey to record cultural values and update the health benefit assessments. However care should be taken to avoid survey fatigue!
- Obtain information on the use of the outdoor parts of the Estate for educational purposes including by Forest Schools.
- Discuss the changes with the Estate team and update the narrative on threats and opportunities.

In addition to these routine updates, there are a number of checks, improvements and additions to the methodology that could be made in future assessments. Those identified so far include:

- Tidy up the Estate boundaries in GIS so that they match OS Mastermap polygons better.
- Integrate the MyForest database into the natural capital map to improve the mapping of woodlands.
- Use CAVAT to generate an assessment of the value of the ancient and veteran trees, which could be compared with the structural value generated by iTree-Eco.
- Check the methodology for the Whole Farm Income assessment with the UK Natural Capital team at the ONS.
- Discuss with the UK Natural Capital team how to do an assessment of the value of wood production at Blenheim.
- Obtain better quantitative data on the use of the Estate by Forest Schools.
- Consider whether the Historic Environment Record and Heritage at Risk data could be better integrated into the assessment.
- Assess the impact of potential habitat improvements on habitat connectivity metrics, including the impact on the connectivity of the Nature Recovery Networks.

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- ⁴⁴ University of Exeter ORVal (Outdoor Recreation Valuation Model) <https://www.leep.exeter.ac.uk/orval/>
- ⁴⁵ Monitor of Engagement with the Natural Environment, available at <https://www.gov.uk/government/collections/monitor-of-engagement-with-the-natural-environment-survey-purpose-and-results>
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