PA2 FEASIBILITY STUDY: BRACKEN MANAGEMENT PLAN

CLEE LIBERTY COMMON, CLEE ST MARGARET

July 2019

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1 INTRODUCTION

1.1 CONTEXT

Clee St Margaret Parish Council own the Clee Liberty Common and have applied to Natural England for funding of a PA2 Feasibility Study: Bracken Management Plan. The common is managed by parishioners and members of Clee St Margaret Commoners Association, which has 40 members all with grazing rights on Clee Liberty. Of these, there are two active graziers on the land with approximately 1600 sheep between them but with rights for up to 3500 sheep and a small number of cattle and horses.

The common is currently part of a national project called 'Our Common Cause' which is working throughout the UK to make common land more relevant to 21st century life by encouraging people to enjoy the commons, whilst responsibly managing them to preserve their natural history and ensure they remain accessible to all. The project also aims to ensure the continuation of grazing on these areas.

1.2 PROJECT LOCATION AND BACKGROUND

The Clee Liberty Common is located in south Shropshire to the north east of Ludlow between the villages of Clee St Margaret and Clee Burf. The common covers approximately 540 acres which incorporates a wide range of land cover. The common is Open Access land with several public rights of way and is a popular spot for walkers and wildlife enthusiasts. At its lowest point the Common reaches 228m ASL and at its highest 506m ASL.

Active management of bracken on the Clee Liberty common began in the 1960's and continues to this day, with a variety of methods being used. The spread of bracken throughout uplands in the UK is widely documented from the 1970's onwards, thought to be partially down to the reduction of cattle being grazed in the uplands.

1.3 AIMS AND RATIONALE FOR THE STUDY

This feasibility study for a bracken management plan aims to:

- Distinguish the varying density and extent of bracken upon the common,
- Identify the ecologically valuable habitats and species on site and discuss which of these will benefit from bracken management,
- Identify possible constraints to a bracken management programme and also sensitive areas within the common,
- Discuss vegetative succession following successful treatment of bracken on site,
- Suggest feasible management options, their achievable implementation, and cost per ha.

2 CLEE CLIBERTY COMMON

2.1 DESIGNATIONS

The Clee Liberty Common falls within Shropshire Hills Area of Outstanding Natural Beauty and is also mapped as a 'severely disadvantaged' area in rural designations from RPA. These are areas where the natural characteristic of the landscape (e.g. geology, altitude, terrain) makes farming more difficult. The site has a Scheduled Ancient Monument called Nordy Bank, an Iron Age hillfort, which occupies approximately 5ha of the north west corner of the site.

2.2 ARCHAEOLOGY AND HISTORY

The hillfort on Clee Liberty has been classified as 'slight univallate', generally interpreted as stock enclosures, redistribution centres, places of refuge, and permanent settlement. There are only around 150 hillforts of this type recorded nationally, making this archaeological feature rare and of national importance. The monument occupies a strong defensive position on Nordy Bank, a spur of high ground running west from the main plateau of Brown Clee Hill.

The hillfort is roughly oval in plan, the ramparts enclosing an area of approximately 3.2ha. The defences include a substantial and well-preserved rampart which averages 1.5m high with five entrances to the enclosure. Building platforms can be recognised, particularly in the north west quarter of the site but later quarrying of the site has encroached onto the earthworks. Historic England map this archaeological feature with a 10-meter boundary as this is considered essential for the monument's support and preservation.

2.3 ECOLOGY OF CLEE LIBERTY

The ecological status of the site has been well documented over the years with several specific reports being produced.

A study of the Common's bryophyte communities (Callaghan, 2014) revealed that a number of nationally scarce species were found, including: *Brachydontium trichodes, Ditrichium flexicaule* and *Hamatocaulis vernicosus* with the latter not only nationally scarce but also awarded full protection under Schedule 8 of the Wildlife and Countryside Act 1981.

A detailed botanical survey of Clee Liberty (Handley, 2013) mapped main vegetation communities and recorded plant species from within 10 monads, made up of 4x4m or 2x2m quadrats.

Recent reptile surveys on Clee Liberty (Arbor Vitae, 2019) found a small population of common lizard *Zootoca vivipara*, believed to be restricted to deep gully channels which are densely vegetated in the upper reaches of the Common.

3 CURRENT BRACKEN STATUS

3.1 METHODOLOGY

The feasibility study has attempted to assess the current status of bracken on the Common. This has considered the distribution of bracken and the density of bracken, both measurements being difficult to tie down with accuracy.

Whereas an absence of bracken or a complete coverage of bracken is easy to identify, the degree of bracken coverage and therefore its distribution is difficult to assess. Evidence of bracken changes markedly over time is influenced by management, ground conditions, weather conditions and altitude. The assessment made in this report was carried out mainly in June 2019 when most bracken was unfurled and in relatively full leaf. However, in some areas, new shoots were still appearing.

The methodology used to analyse bracken coverage centered around using desktop ArcGIS digital mapping software and digital data, augmented by GPS field surveys. The following data was used to construct a GIS digital map model of the site:

- Site boundary and field parcels from the Rural Payments Agency

- OS MasterMap data and Protected Site data from Natural England
- Public Rights of Way Data from Shropshire County Council
- OpenMap, OpenRiver and Terrain height and contour data from Ordnance Survey
- Aerial Photography and various GPS ground survey data generated by ourselves

OS map data was used to build a model in ArcGIS of the structure of the site and public rights of way. Detailed aerial photo interpretation then formed the basis of building a model of the extent of bracken covering the site, using latest available aerial photography (updated several times during the course of the survey).

Maps were produced in ArcGIS and printed on a Large Format Plotter to help plan and inform various detailed ground surveys using High Accuracy GPS and a Trimble mobile device running Mobile ArcGIS software. These ground surveys were undertaken throughout the course of the study, crisscrossing the site, testing and refining the bracken extent model. The model was updated and corrected over the course of these surveys and further validated by re-surveys and discussions within the Arbor Vitae team.

Data was then analysed in ArcGIS to produce a model of the extent, distribution and density of bracken on the site. While not exhaustive or 100% accurate, we believe the model nevertheless gives best available evidence within the time constraints of the study. Given the spectrum of bracken density from 1% to 100%, a decision was made to map bracken density in four broad categories, namely thin (up to 30%), medium (30-60%), dense (over 60%) and very dense (100%). This is necessarily an approximate average but gives an overall picture of current density.

There are very few areas where bracken is completely absent. The main central area of dense gorse is almost devoid of bracken and small patches of other vegetation (acid grassland, rush pasture and mire) have little or no bracken. Main pathways are generally free of bracken. The south eastern plateau within the site is dominated by other vegetation types and bracken is almost absent.

3.2 RESULTS

Bracken density categories are described, as follows:

Thin: up to 30% cover. This category includes a number of areas where bracken control has been effective. It includes some areas where bracken was formerly dense but where grassland may not yet have become established. It also includes at least five extensive areas where acid grassland now predominates although bracken still persists.

In the areas where acid grassland predominates and the cover of bracken is less than approximately 30%, there is usually no evidence of dead bracken stems on the ground. The ground layer species beneath the bracken are those of acid grassland, with few shade tolerant species present.

Typical species include heath bedstraw, tormentil, sheep's sorrel, common bent, sheep's fescue, wavy hair grass and sweet vernal grass.

Medium: 30%-60%. These areas are predominantly bracken with grassland species surviving beneath. Dead bracken stems may be present beneath but there is no build-up of bracken thatch. In some cases, these areas have been previously treated but, either management has been of limited success or, bracken is becoming re-established.

In addition to light-demanding acid grassland species surviving in these areas, a number of shade-tolerant species also remain including wood sorrel, common violet, foxglove and barren strawberry.

Dense: over 60% cover. These areas are almost exclusively dominated by bracken with few other species. Bracken thatch often forms a significant layer of humus and this prevents the establishment of other species. Acid grassland species survive but at low cover, although a number of bryophytes are more prominent. Shade-tolerant species such as wood sorrel are frequent in some areas. Bluebell is found in these dense bracken stands in some areas on lower slopes.

Very dense: 100% cover. These areas are mainly restricted to inaccessible parts of the Common where no treatment has been possible. The bracken stands in these areas are tall and dominant, preventing growth of almost any other species. The bracken thatch can be 300-450mm in depth and in some places large mounds of decaying thatch are present.

Figure 1 shows the general distribution of bracken, as part of a habitat plan and Figure 2 shows more detail of bracken densities, land coverage of which can be found in Table 1 below. Comparison with the historical management plan (Figure 3) and also the constraints plan (Figure 4) are useful in indicating some of the reasons for the current distribution.

Table 1. Extent of bracken by density.

Density	Area (ha)
Thin	38.4
Medium	24.6
Dense	77.8
Very dense	13.5

4 FEATURES OF CONSERVATION CONCERN

4.1 HABITATS

An assessment of the site has been carried out to identify the presence of all features, including habitats and features, which are of conservation value. This has been achieved through fieldwork and reference to past studies where available. A detailed vegetation map has not been produced, this not being one of the aims of the study. However, approximate locations of features are discussed. The features are not presented in any particular order of merit.

Scrub

Western gorse (*Ulex gallii*) is very common and even dominant in two main areas, as seen on Figure 4. Its current extent is approximately 9.5ha. Whilst an important habitat for certain bird species such as linnet and stonechat, its inevitable spread removes grazing area and also has implications for the integrity of the hillfort. Common lizards are present on the edge of a gorse area and it is likely that gorse provides useful refuge habitat for this species, especially where it grows on undulating ground with south facing banks or slopes. Other species of scrub or trees are scarce and are limited to isolated bushes or small trees which have somehow grown above browsing height. These include hawthorn, ash, rowan, grey willow and sycamore. These provide important song posts for birds during territorial displays as well as perches for predators such as kestrels.

Standing water

One small pool exists within the former quarry area at the summit of Clee Liberty.

Running water

As shown on Figure 4, a number of streams arise on the north facing slopes of the hill. These generally form from springs and flushes and many are seasonal. They mainly flow in a northerly direction, and often flow through step sided narrow gorges, in some cases up to 4-5 metres in depth. A wide range of species are directly associated with these streams and their banks.

Exposed rock

Rock exposures exist both as natural features on lower slopes and as a result of past quarrying. Whilst of probable value to species such as common lizard, they generally do not support diverse plant communities. This is partly a result of their acid conditions but also due to sheep grazing.

Grassland communities

U1 Acid grassland: Festuca ovina – Agrostis capillaris – Rumex acetosella type

This is the predominant grassland type on lower, drier slopes and is the classic 'acid grassland' of the Clee Hills. It is relatively species-poor.

U2 Acid grassland: Deschampsia flexuosa, Vaccinium myrtillus sub-community

This community is more common on upper slopes of the plateau, usually as part of a matrix with U5 and M23.

U5 Acid grassland: Nardus stricta – Galium saxatile type

This is more widespread on the upper slopes, occupying dry sites as well as damper areas.

Mire communities

These communities are mainly associated with springs and rills and often occur in very small, restricted areas. They lie mainly high on the north-facing slopes and are not generally in areas likely to be feasible bracken management plots.

M6c Carex echinata – Sphagnum recurvum mire

Mainly located on the upper, flatter plateau where there is impeded drainage at the upper reaches of catchment areas. These areas merge and develop often into M23 communities with higher concentrations of *Juncus* species.

M10 Carex dioica – Pinguicula vulgaris mire

A few small areas near quarry workings.

M23 Rush pasture: Juncus effusus/acutiflorus – Galium palustre type

Small areas of this are found near spring-fed flushes and where drainage is impeded near watercourses.

M32 Philonotis spring

Frequent in Pole Gutter.

M35 Ranunculus omiophyllus – Montia fontana rill

One small area within the old quarry workings.

M37 Palustriella commutate – Festuca rubra spring

One area where spring forms seepage on north slope of hill.

Bracken communities

U20a Pteridium aquilinum– Galium saxatile

This is a variable community, dependent on the density of the bracken and thence the degree of shade and amount of litter, as discussed above.

Although very poor in species where densest, it serves to create suitable conditions for a range of shade and semi-shade tolerant species. These include bluebell, common violet, wood sorrel and barren strawberry. The lower slopes of the site, particularly towards the west, appear to support the bracken communities where these woodland-type species best survive.

Although bracken in itself is not a feature of high ecological value, it nevertheless creates conditions which can be important for other species including invertebrates, birds, small mammals and reptiles.

4.2 SPECIES

Mammals

As far as is known, no detailed mammal surveys have been undertaken on the site. However, the following species have been observed during the course of this survey:

- Badger (one sett on site)
- Rabbit – sporadic
- Mole – rare
- Bank vole – occasional
- Wood mouse - occasional

Birds

Limited information on birds is currently available but a list of species observed on the Common during this study has been collated (see Appendix 2). Birds of Conservation Concern include curlew, snipe, stonechat, willow warbler, skylark, green woodpecker, kestrel, cuckoo and yellowhammer. Species recorded there in the past include ring ouzel and tree pipit. Whinchat has not been recorded although the conditions are suitable, as indeed they are for nightjar.

Areas of gorse appear to be of most value to linnet, stonechat and goldfinch and these species were not observed away from this habitat. Skylark, meadow pipit, tree pipit and willow warbler are all know (from other sites) to nest in areas of bracken.

Amphibians

Two species were recorded during this study: common frog and smooth newt. Breeding sites for amphibians are few although a small pool in the former quarry supports both these species. Common

frogs were also found in stream gulleys, possibly having been able to breed in small pools within the stream course.

Reptiles

Recent reptile surveys on Clee Liberty (Arbor Vitae, 2019) found a small population of common lizard *Zootoca vivipara*, believed to be restricted to deep gully channels which are densely vegetated in the upper reaches of the Common. No adders have been recorded during the most recent survey, although populations exist at Titterstone Clee Hill. The most recent survey included the positioning of 150 'refugia' throughout the most suitable areas on the common. These were checked on a weekly basis for 7 weeks.

Invertebrates

No known invertebrate surveys have been carried out at the site, although a recent butterfly walk was undertaken.

Butterfly species recorded during the study include small heath, small copper, meadow brown, painted lady, wall, ringlet, common blue, red admiral, green hairstreak.

It is very noticeable than many more invertebrate species are found in the sheltered stream valleys. This is partially due to local microclimate but also due to the greater availability of nectar producing plants alongside the streams.

Flowering plants

A list of flowering plants recorded on the site is attached in Appendix 3.

The plant communities of most notable conservation value include:

- All mire communities. These are mainly located on the upper plateau on rush pasture and also at springs and seepages on the north facing slope above Pole Gutter.
- Streamside communities. Narrow fringes of vegetation along stream sides include a range of wetland, grassland and woodland species including several ferns.
- Bracken with woodland species. An area below Nordy Bank includes dense bracken with a range of woodland species including bluebell, common violets and wood sorrel.
- Acid grassland. Much of the acid grassland is of low botanical diversity although the very high grazing levels may conceal the presence of more uncommon species. Of notable exception are areas of grassland on the upper plateau towards the eastern end of the site where other species such as bilberry and occasional heather are found. Small areas of acid grassland on very thin soils on mounds and hillocks near Nordy Bank support a range of species not found elsewhere including carline thistle and wild thyme, along with a range of early annuals.

Bryophytes

The bryophyte survey of 2014 recorded 190 taxa of which three species are nationally scarce including: *Brachydontium trichodes, Ditrichium flexicaule and Hamatocaulis vernicosus.* The latter is not only nationally scarce but is also awarded full protection under Schedule 8 of the Wildlife and Countryside Act 1981. This prohibits picking (uprooting or destruction) and sale (live, dead, or derivative). There are 6 patches of this protected species, all of which are within the upper bounds of the Common where bracken management will not be necessary.

4.3 HABITATS WHICH WOULD BENEFIT FROM BRACKEN MANAGEMENT

Acid grassland

This study considers that an increase of approximately 40 hectares of acid grassland is feasible in the short term. This equates to those areas of bracken which have been judged to be 'thin' or 'medium' density and where grassland species survive under light to moderate shade conditions.

Heathland

An increase in the availability of acid grassland may result in an expansion in heathland habitat on the upper slopes, assuming that grazing levels are also maintained or lowered. Although species are present which would constitute heathland (bilberry, heather), they do not at present attain 'dwarf shrub' height and are maintained as low carpets. A decrease in grazing pressure may allow better establishment of heathland and possibly its extension. The current area of potential heathland extends to approximately 8 hectares.

Mire communities

A reduction in grazing pressure due to availability of increased areas of grassland may result in less pressure on mire habitats, especially seepages and flushes. These are fragile habitats due to the ground conditions and are vulnerable to trampling. These occur in such small areas that it is difficult to assess extent. However, the rarer species which they support would be provided with a greater likelihood of flowering and seeding.

5 BRACKEN MANAGEMENT

5.1 HISTORICAL BRACKEN MANAGEMENT

Bracken has been managed on areas such as Clee Liberty over many years, including having been cut and carted for animal bedding for decades or even centuries. In the last 60 years at least, management of bracken on Clee Liberty has been directed at controlling its density and spread in order to maintain the area of grazeable land and the balance between bracken and grassland.

A number of techniques have been employed and this has been recorded in detail from 2007 onwards. Figure 3 shows approximate areas where different techniques have been carried out in the past and this is based on discussions on site with parish council members and graziers responsible for recent management.

A summary of different techniques employed has been given below:

Cutting: This method has been used from the 1970's to the mid 2000's to weaken the bracken. Flail or disc mowers are used by volunteers which helps to prevent the spread of bracken and stunts its growth, but does not eradicate it from established areas. It needs to be done each year to prevent revival and is labour intensive for all involved.

Crushing: In 2007 the Parish Council invested in a bracken crusher which is a roller system attached to a tractor, designed to bruise bracken and prevent the supply of nutrients to the roots and rhizome system.

Herbicide application: Asulox has been used on the Common through aerial spraying below the Nordy Ring and spraying from a quad bike. Spraying has been used where crushing is not feasible due to terrain constraints.

Trampling by sheep: Supplementary feeding in areas of dense bracken has been used as a bracken control method via the trampling from sheep hooves which damages bracken rhizomes and breaks down thatch.

A detailed overview of the land management, split into yearly records can be found in Table 2.

Table 2 Summary of historic bracken management of Clee Liberty.

Method:	Spray			Trample			Crush			Mow			
	Year												
Section	07	08	09	10	11	12	13	14	15	16	17	18	19
1	S							C				C	C
2	S	C						C		C	C	C	
3		T C		C					C				
4	S	T C		C					C				
5													
6		S	C					C	S				
7	S	C					C			C	C		
8	S	C					C			C	C		C
9			C		C			C			M	C	C
10										S			
11		T	T	T	T	T	T	T	T	C			
12											S		
13							C		S				
14								C					
15									S				
16									C	C			
17			C										
18		T C	T C	T C	T C	T C	T C	T C	T C S	C	T C	T C	

5.2 RESULTS OF HISTORICAL BRACKEN MANAGEMENT

This assessment of the effectiveness of various control methods is based on one set of observations and does not have the benefit of long-term field study. However, certain general conclusions are possible:

Herbicide application

This has generally been very effective where carried out and can achieve control of up to 90%. However, when used in areas where no grassland vegetation exists beneath the bracken, the result can be extensive areas of bare ground or an invasion by undesirable species.

This study has examined at least three areas on the northern slopes above Pole Gutter where eradication by herbicide has been, initially at least, extremely effective. Estimates of present vegetation coverage on the site (using quadrats) indicates that bare ground still covers up to 30-90% of the ground surface with bracken having become re-established to cover up to 5-30%. In some areas bryophytes (often associated with 'tumps' of bracken thatch) extend over significant patches. The desired species of acid grassland is often very limited and presumably reflects the existence or otherwise of grassland species prior to spraying.

A frequent occurrence following spraying of dense bracken areas is often the incursion of undesirable species. These are those which have the ability to spread seed over wide areas either because of their unpalatability to stock (foxglove, sheep's sorrel, thistle, rush) or the high dispersal rates of seed (foxglove, thistle, annual meadow grass). It is notable that the first and most successful acid grassland species to recolonise these bare sites is sheep's sorrel which can form extensive pure patches. This is presumably due to the fact that it appears only lightly grazed and therefore can manage to produce seed. Other grassland species are very slow to recolonise, presumably because of the lack of opportunity (due to grazing pressure) to flower and seed.

Cutting/crushing

This technique has been used regularly on several areas, generally where contours are flatter and where bracken was always less dense. Although bracken in every case is still present, it has been reduced to a cover of only 5-10% in some places. Here, grassland now covers 90-100% of the ground surface and incursion of unwanted species is minimal or non-existent. Based on ongoing observations, crushing on the Common appears to be much more successful at reducing bracken than cutting. This finding contradicts those of published research which suggests cutting is the most effective method when controlling bracken. Some areas have experienced acid grassland re-establishment following management which includes removal of bracken thatch.

Trampling

The use of high stock densities to crush rhizomes and to eliminate bracken thatch appears to have the desired effect. Several areas where stock have been concentrated around mineral licks, for instance, have no bracken. However, this can result in completely bare ground (Appendix 1) or, subsequently, in an invasion by undesirable species responding to the elevated nutrient status. Several former feed stations are now marked by large amounts of 'weed' species such as nettle, spear thistle and creeping thistle. These can then spread to other areas of disturbed ground and in themselves become a problem requiring treatment. The exposed bare ground around such feeding stations also poses a soil erosion risk with repeated trampling by large numbers of stock.

5.3 OTHER EXAMPLES OF BRACKEN MANAGEMENT

Baildon Moor, Yorkshire 2011: An area of open moorland covering approximately 300ha with several archaeological features of interest including pre-historic rock carvings and 19th century industrial archaeology. In 2011 a bracken management plan was commissioned, as heathland and acid grassland were becoming inundated with bracken. 85% of the moor's bracken was dense with a deep litter layer underneath, denude of alternative vegetation. In some areas, characteristic species such as heath bedstraw, mat grass, and bryophytes were found at ≤10% density.

The usual management options were considered: spraying with Asulam using a suite of application methods, and bruising/cutting the bracken where the land allowed. The very dense areas of bracken posed some difficulties where regenerative vegetation would not be readily available if the bracken canopy were to be removed. Areas of exposed soil are vulnerable to erosion and therefore habitat creation works were recommended to stabilise and recolonise the land with suitable species.

Moderately dense bracken could be treated without the need for habitat creation works but land with slopes of 15 degrees or more should be considered as an erosion risk. Land with a shallow gradient should be targeted. At this particular site, chemical treatment was suggested with substantial buffer zones against water courses, cutting of bracken was easily completed but repeated long-term treatment would be necessary to have any effect, and woodland regeneration on areas of the moorland was also suggested as a management option. The development of target vegetation following bracken management requires a combination of control and habitat restoration.

Cutting can be used as a long-term control and the best results are achieved by cutting twice per year. In a study based on bracken control, Cox (2007) found that bracken in test plots which was crushed three times in one year actually increased its growth the following year. The study concluded that bruised bracken fronds remain alive and intact for up to 7 weeks following the crush and that there was no significant difference between the photosynthetic and transpiration rates in bruised and untreated fronds. The study also investigated the effects of Asulam and found that repeated application of the selective herbicide resulted in a reduction in future growth of bracken.

6 FEASIBILITY OF MANAGEMENT TECHNIQUES

6.1 AVAILABLE TECHNIQUES

Table 3. A review of the available bracken management techniques.

Method	Details	Advantages	Disadvantages
Mechanical			
Cutting	Cutting the bracken to reduce its photosynthetic capacity and therefore starve the below-ground rhizomes. This method helps to weaken the plants over-winter reserve and the vigour with which it returns the following year. Methods include flail or disc cutters, and Robocutters.	Breaks up material into smaller pieces which decompose more quickly without adding to an underlying thatch. Can be done from tractor, ATV, or by hand if the labour is available. Research has shown that this is the most effective non-chemical method to	Total eradication using this method *alone* is unlikely. Cannot be carried out during the bird nesting season and other species should be considered including reptiles and butterflies.

	Cut bracken can be collected for biodigesters/biofuel but usually the heat value compared with another biofuel is not high enough to be commercially viable. This method also relies on the persistence of dense bracken stands which is counter intuitive in this case.	reduce bracken cover (Cox, 2007). Clee Liberty Parish Council disagree based on their previous experience. Bruising has been shown to reduce bracken more effectively. Robocutter can be controlled via remote control and functions on slopes up to 55 degrees.	Difficult terrain may limit the extent to which this method can be used.
Bruising	The xylem vessel resides within the stem of the plant and is responsible for transpiration of water from the rhizomes to the leaves and the phloem moves the products of photosynthesis (mainly glucose) to the rhizome. Bruising is intended to crush the stems of bracken, effectively causing a haemorrhage within the main stem and therefore starving the leaves and the rhizomes.	Can be carried out several times per year (outside of bird nesting season) for relatively low cost. Apparatus can be mounted on ATV or tractor.	Only effective when bruising takes place at the optimum time in the growth cycle of bracken. This is a short window mid-late July. Total eradication using this method *alone* is unlikely. Cannot be used on difficult terrain or sensitive archaeological features.
Use of livestock	A balanced stocking regime using cattle and fewer sheep on badly affected areas can be used. Cattle trampling is recognised as the most effective method in reducing bracken cover and it has been observed that, over 11 years, a herd of Highland cattle were able to eradicate bracken from a 2ha plot in the Scottish uplands (Parry, 2019).	Foraging amongst bracken helps to reduce the amount of protective litter around the plant base (Ader, 1988). Concentration of stock on badly affected areas helps to amplify the impact of trampling. Animals ranging amongst bracken reduces the density and eventually the height of the plant.	Potential damage to soil. Bracken can be toxic to stock if ingested if there is no alternative food source. May require fencing.
Chemical			
Aerial application of Asulam	Using a helicopter, this method is suitable for primary treatment of large areas of bracken. Not suitable for small patches or interspersed areas of bracken or where sensitive ecological features can be found. Strict buffer zones should be applied to flushes and watercourses NB LERAP	Effective when treating areas of dense bracken which can be followed up. Good for areas which are inaccessible by vehicles.	Has to be followed up by thorough treatment on a regular basis which can become costly. No effect on the bracken litter underneath.

	In the UK alone between 1980 and 2002, 1057km^2 was treated using aerial application of Asulam at a cost of £12m (Pakeman *et al.,* 2005). Using Unmanned Aerial Vehicle as a method of delivering herbicide to land on a commercial basis is not currently legal in the UK but will likely be an available option in the near future. .		
Tractor/ATV with mounted boom or weed wiper	Suitable for shorter/patchy areas of bracken which are part of a more diverse vegetative community. Generally, not acceptable on archaeological sites as heavy machinery can cause damage to monuments. Recommended herbicide: Asulam (applied in short window late July). Has LERAP restrictions for use near water courses. Glyphosate can be applied by weed-wiper in spring/early summer when it will kill foliage but have no impact on rhizomes. Treatment in July-August will have good control of rhizomes but is difficult practically on tall, dense bracken. Multiple follow up treatments using Asulam is more effective than one/two treatments alone (Stewart *et al.,* 2007).	Cheap and efficient use of herbicide. Smaller buffer zones can be implemented as this method has a more refined application. Can be used as follow up treatment on previously treated areas where the land allows.	Booms may not spray efficiently on rough ground. Chemical run-off can occur. Less effective where frond density and height is increased. Produces uniform treatment areas which impact the natural landscape.
Spinning disc sprayer e.g. Micron Ulva+	Suitable for large areas of short bracken or small areas of dense bracken. This method uses liquid atomisation to reduce the total amount of herbicide needed and delivers appropriate droplet size based on target vegetation.	Waterless spraying for difficult areas and therefore lighter to carry. Can be used easily as follow up treatment or missed areas.	Depends on weather conditions for application. Must be steady wind of 5 to 10km/hour.

6.2 CONSTRAINTS TO MANAGEMENT

There are a wide range of constraints which restrict the areas in which bracken can be treated or which determine the method to be employed. These include physical, environmental and cultural constraints. The following are highlighted on Figure 4:

Slope and uneven ground

Several parts of the site lie on ground which is too steep for the use of agricultural machinery or even possibly alpine machinery. This covers approximately 23 ha of the site. Moderately steep slopes, where agricultural machinery can and has operated, occupy approximately 93 ha. These lie chiefly on the north facing slopes above Pole Gutter. Although accessible, large sections of this area are intersected by streams and gulleys with resultant localised steep slopes (Figure 5).

A large section of the area to the south west of the stone road is relatively flat and appears very accessible for treatment by machinery. However, some areas have localised surface undulations resembling ridge and furrow and other areas are pitted with presumed surface quarry excavations. These localised surface irregularities, though not large in scale, can create problems such as grounding for farm machinery and crushing/cutting equipment.

Historic features

Nordy Bank hillfort covers approximately 5ha. This includes areas of bracken on its flanks and extensive gorse within its ramparts. No machinery use is permitted and management work has to be carried out by hand.

Other historical features include trackways, former quarries and other excavations. Since machinery work in these locations is in any case impractical, they do not form constraints.

Watercourses

The eastern section of the Common, mainly lying above Pole Gutter, is dissected by a dozen or so streams and watercourses. These mainly arise from springs or seepages and often develop into significant gorges. Some have exposed sandstone. Due to the increased shelter, the damper conditions and some degree of protection from sheep, these stream courses support a wide assemblage of species not otherwise found on the hill. These include several other fern species including hard fern and lemon-scented fern.

Features of ecological interest

Several features of ecological interest lie outside the bracken area and do not constitute constraints. These include features associated with the quarry (rock faces, pools, flushes) and areas of acid grassland on upper slopes with bilberry.

Within the bracken area, the main ecological features are the flushes, streams and gorges, as mentioned above.

- **Vegetation** – Areas of acid grassland within hollows and hummocks south east of Nordy Bank include several species such as wild thyme and carline thistle not present elsewhere. All mire vegetation, especially that associated with springs, seepages and stream-sides, is floristically rich and of ecological interest. One or two small areas of dense bracken, particularly on the steep eastern flanks, support the protected species bluebell.

- **Reptiles** – small population of common lizards, probably restricted to gulleys and hollows on upper slopes, possibly where shrub (gorse) cover exists.
- **Birds** – all bracken areas have potential to support breeding and foraging birds and the constraint for these areas is to do with timing of management which should avoid the period April to August. Gorse areas appear important for birds such as linnets and stonechats but, having no bracken, will be unaffected.

Public footpaths

Several public footpaths and other 'desire' routes exist. These may be a constraint when chemical bracken control is being employed.

6.3 FEASIBILITY

This section considers the feasibility of carrying out bracken management on Clee Liberty Common. Presented here is a synthesis of a wide range of factors which have been explained above, and include:

- Extent of the bracken problem and its distribution,
- Effectiveness of various methods of control,
- Accessibility,
- Predicted benefits to grazing,
- Environmental impact of bracken management,
- Approximate costs of each method,
- Availability of methods and labour.

Each category of bracken density is considered individually below in Table 4.

	Table 4. Evaluation of feasibility of bracken management on Clee Liberty Common. (All figures are based on estimates from a range of sources in July 2019).								
	Extent	**Accessibility (slope)**	**Effectiveness**		**Benefit to grazing**	**Potential environmental impact**	**Cost**		**Approximate area available for management**
			Mechanical	**Chemical**			**Mechanical**	**Chemical**	
Very dense bracken	13.5ha 5.9% of site	9.54ha on steep 2.7ha on medium slope 1.2ha on even	Difficult but feasible using correct machinery (e.g. Robocutter).	Possible by helicopter. LERAP applies. *	Very low due to lack of replacement vegetation availability.	Damage to bluebell areas, soil erosion risk on steep slopes, chemical run-off.	£850/wk + delivery. Approximately £300/ha based on 1ha per day.	£240/ha.	3.9ha readily available to management. 9.54ha via appropriate machinery.
Dense bracken	77.8ha 34.3% of site	10.8ha on steep 39.9ha on medium 27.1ha on even	Feasible using tractor/ATV with crusher/flail or Robocutter.	Tractor or ATV spray or weed wipe all except 10.8ha. LERAP applies.	Long term acid grassland regeneration through gradual bracken reduction.	Bare soil where chemically controlled with no replacement vegetation. Soil erosion on steep slopes, chemical run-off. Could result in increased acid grassland.	Robocutter: £850/wk + delivery. Approximately £300/ha based on 1ha per day. Tractor crush: £45-65/ha.	Tractor/ATV spraying: £55-100/ha	67ha readily available to management.
Medium bracken	24.6ha 10.8 of site	2.9ha on steep 6ha on medium 14.4ha on even	Possible using above techniques on majority of medium density bracken.	Tractor or ATV spray or weed wipe majority. LERAP applies.	Medium-long-term grassland regeneration. Short term benefits where management regime is regular in areas of intact grassland sward.	Low risk option when constraints are observed. Increase in acid grassland with resultant reduction in grazing pressure on other habitats.	Robocutter: £850/wk + delivery. Approximately £300/ha based on 1ha per day. Tractor crush: £45-65/ha.	Tractor/ATV spraying: £55-100/ha	20.4ha readily available to management.
Thin bracken	38.4ha 16.9% of site	All areas on even ground.	Possible using above techniques on all of thin density bracken.	Tractor or ATV spray or weed wipe all. LERAP applies.	Medium-long-term grassland regeneration. Short term benefits where management regime is regular in areas of intact grassland sward.	Low risk option when constraints are observed. Increase in acid grassland with resultant reduction in grazing pressure on other habitats.	Robocutter: £850/wk + delivery. Approximately £300/ha based on 1ha per day. Tractor crush: £45-65/ha.	Tractor/ATV spraying: £55-100/ha	38ha readily available to management.
* LERAP= Local Environment Risk Assessment for Pesticides.			**Area of land readily available for bracken management (not including local conditions/buffer zones):**						**129.3ha**

7 SUMMARY AND DISCUSSION

The feasibility study of Clee Liberty has examined the scale of the bracken 'problem' on the Common, the efforts made over 20 years to deal with it and the results of that management. The Common has to fulfil several functions including providing grazing for sheep and horses, supporting a range of habitats and species, protection of historical features and providing an area of open access for walkers and others. The control of bracken is carried out largely to maintain bracken/grassland balance but also has to respect the needs of its other functions.

The study has measured the extent of the bracken problem and identified opportunities for control, given certain constraints, on approximately 129ha of bracken. Availability of resources in the future is uncertain but dependable and long-term access to machinery and labour is vital if significant control is to be achieved.

The feasibility of managing bracken by a variety of techniques and over a range of terrains has been examined. During this process, a number of key points have been raised which may stimulate further discussion:

Importance of having replacement vegetation

This survey has noted that in areas where bracken is relatively thin and where a reasonable coverage of grassland species survives, regrowth of grassland has been successful and relatively rapid. Anecdotal evidence from older graziers describes how some of these areas have been transformed, over several decades, from very dense bracken, with thatch beneath and very little other vegetation, to acid grassland with thin bracken.

However, treatment of areas where bracken has been dense, often with deep bracken thatch, regrowth of grassland species has been slow and sporadic for up to 20 years due partly to the lack of nearby seed sources and partly due to the difficulty of grassland species seed finding suitable germination conditions in thick thatch. Bare ground, or at best bare earth dotted with bryophytes and lichens, persists for some time and is susceptible to erosion. Moreover, it can be invaded by other less welcome species including foxglove, gorse or arable weeds such as nettle or thistle, although anecdotal evidence suggests that other than gorse, most of these species do not persist for very long. However, it must be accepted that a return to grassland is extremely slow and efforts should be made to minimise the amount of bare earth that is exposed by any treatments.

Use of herbicides

In light of the above, and the often-high rates of bracken eradication with herbicides, it appears sensible to target this treatment on areas where there is already a reasonable grassland flora beneath the bracken, to reduce the density of the bracken without leaving bare earth. Where bracken is very dense and thatch has stifled the survival of other species, extensive bare earth will result from herbicide application unless the application is managed so that kill-rate is not total and some thatch is allowed to remain to mitigate the effect in the shorter term.

Use of trampling

Although intense concentrations of sheep do achieve localised elimination of bracken and damage to rhizomes, for example on pathways and on supplementary feeding sites, there is collateral environmental impact, especially in areas where feeding takes place, due to increased nutrients and encouragement of weed species. If supplementary feeding is necessary for commercial and animal welfare reasons, then it is important that its ecological impact is minimised by concentrating it in areas

of dense bracken whilst ensuring that the sites are moved regularly in order to avoid exposure of bare earth and potential soil erosion. The temporary fencing of feeding areas in order to prevent access by horses to sheep mineral buckets tends to result in feeding areas becoming long-term (due to the practicalities of moving fences).

Measures of success

The success of bracken treatment should be measured not only in the percentage 'kill' of bracken in any one area but rather on the degree to which it allows a replacement acid grassland vegetation to become established. From an agricultural and environmental point of view, 100% kill of bracken followed by extensive bare ground is not a success: for this reason, it is recommended that treatment of very dense areas should be done sensitively and selectively to minimise the "brown patch" effect.

Time scale

All evidence from other sites points to the fact that bracken eradication is a long-term project, dependent on consistent and regular treatments. The most cost-effective treatments with most positive results for grazing and environmental benefits are usually where effort is expended on keeping manageable areas under control rather than spending resources on 'difficult' areas. However, given that dense bracken areas are problematic for a number of reasons (stock management, low ecological diversity, cover for predators, inaccessibility to walkers), if additional resources become available via environmental grants, then treatment of these areas will have large benefits as long as certain precautions are followed.

Grazing pressure

Whilst grazing pressure has some benefits in controlling bracken, types of grazing and timing is important. It is well documented that grazing by cattle as opposed to sheep has a much more beneficial impact on bracken. The impact of sheep is that grasses and other flowering plants do not get chance to flower and seed. Seed sources for revegetating bare ground are therefore not available. Reduction of sheep numbers for a few weeks in July and August would enable more seed production to occur. This would also have large benefits to invertebrates due to increased flowering/nectar sources, with a knock-on benefit to birds with greater abundance of insects.

Landscape impact

Location and shape of treatment areas need to be carefully considered, especially when treatment is by herbicides which can have immediate and dramatic results. Effect on landscape quality should be minimised by avoiding rectangular blocks and working in irregular blocks using natural features as boundaries.

Carbon neutrality

Given the recent statement by NFU committing British agriculture to carbon neutrality by 2050, the impact of bracken management in carbon sequestration needs to be considered.

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9 FIGURES

Figure 1. Vegetation cover at Clee Liberty Common.

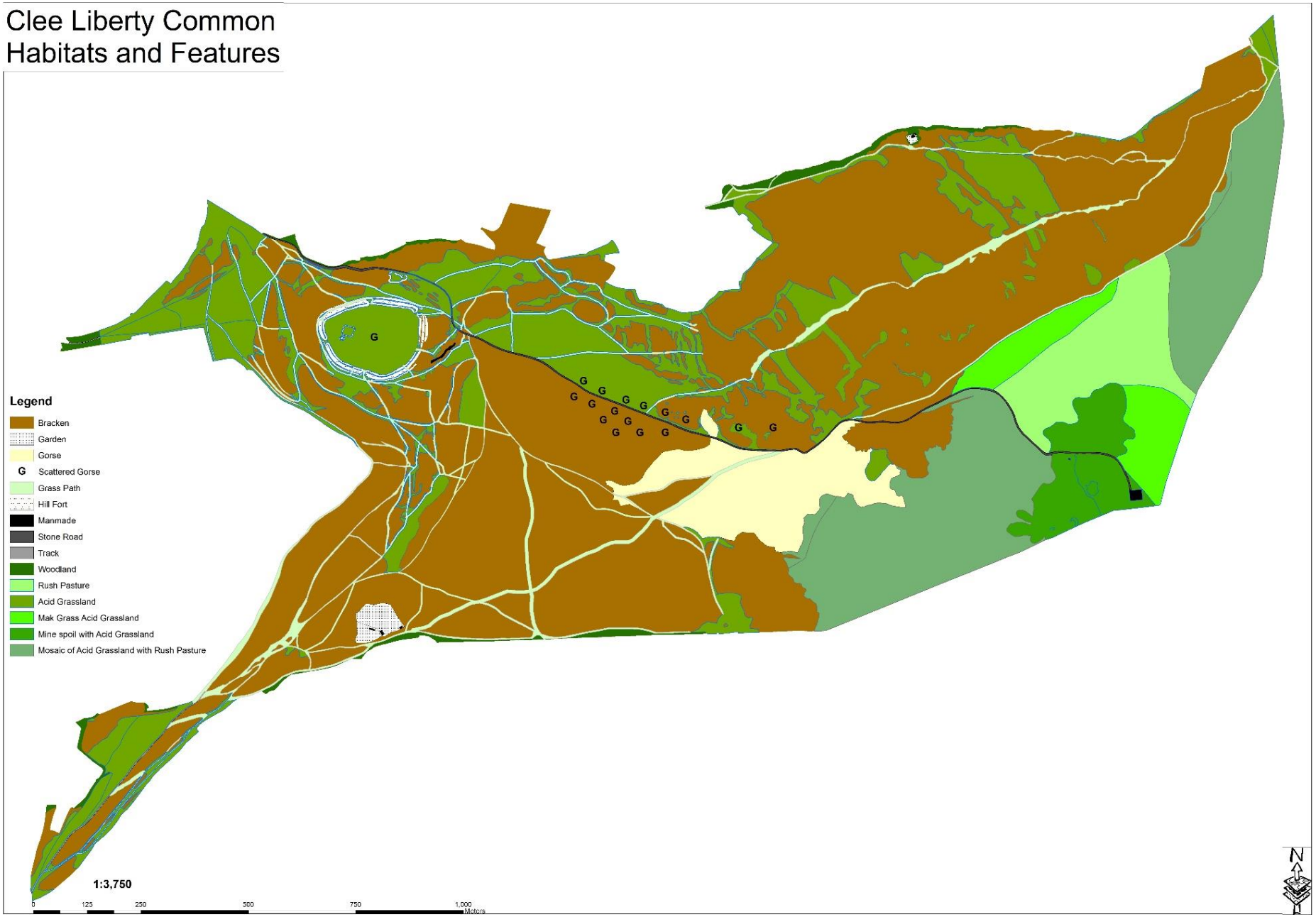


Figure 2. Bracken cover at Clee Liberty Common.

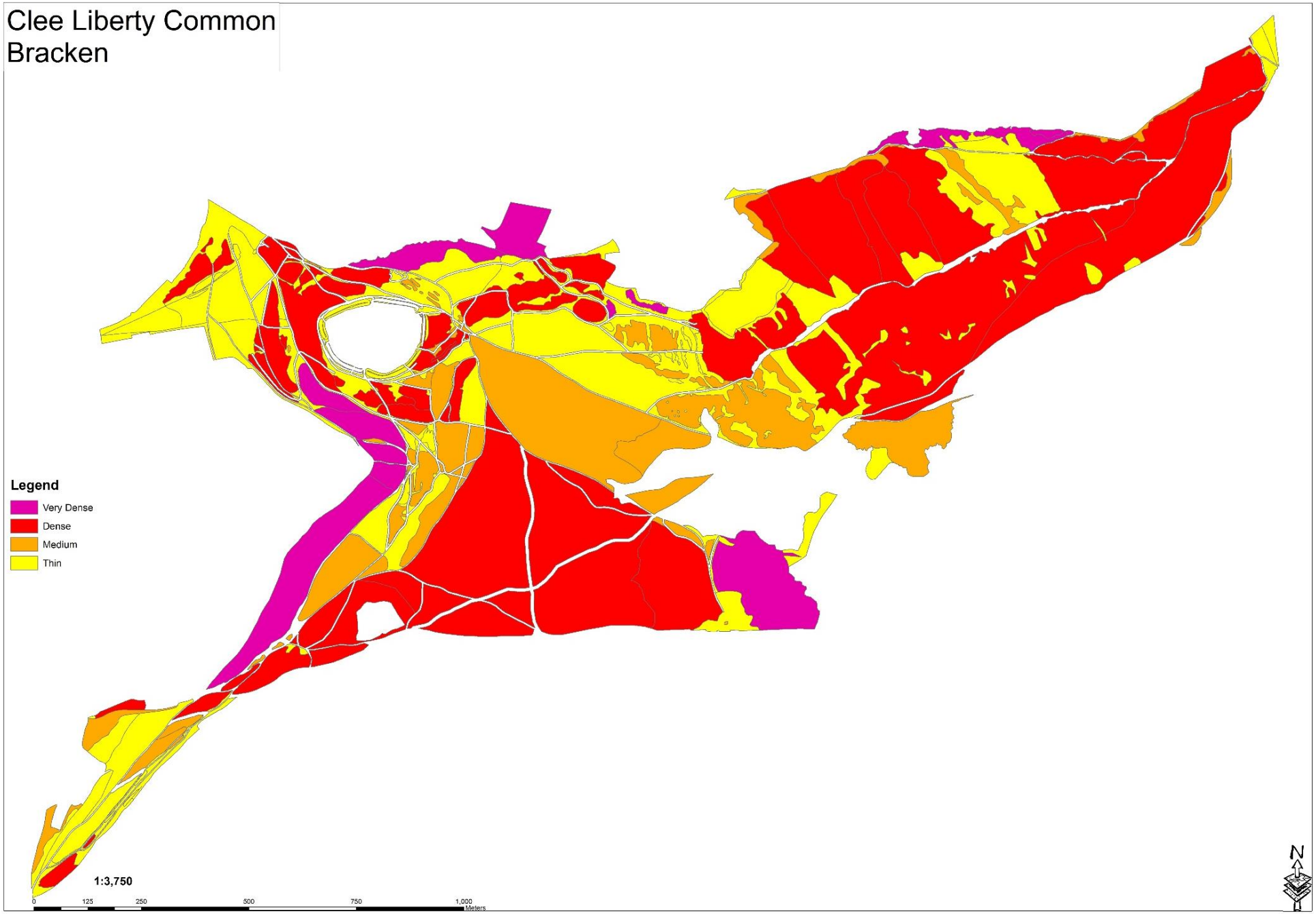


Figure 3. Historical bracken management at Clee Liberty Common, indicative map.

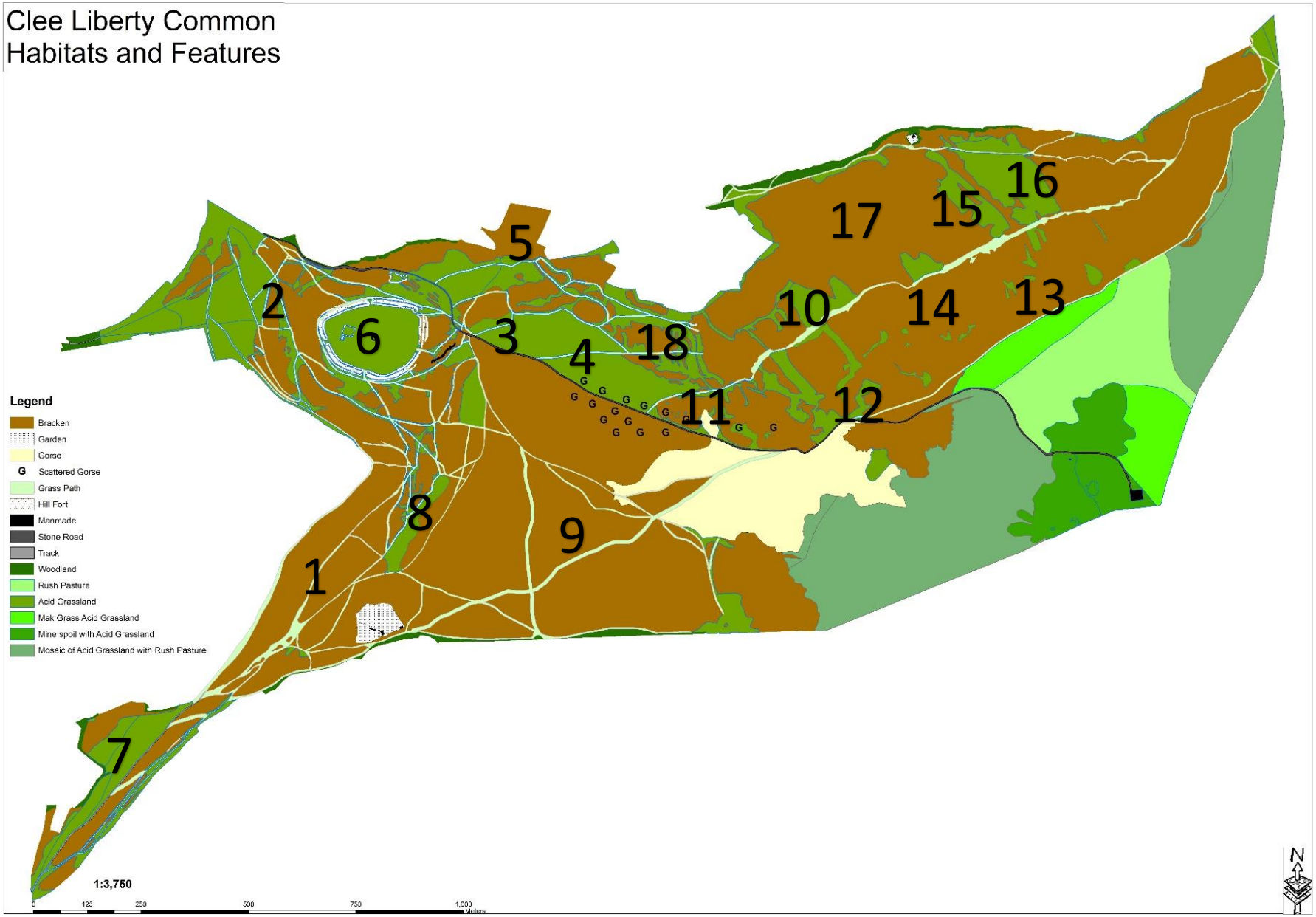


Figure 4. Constraints to bracken management at Clee Liberty Common.

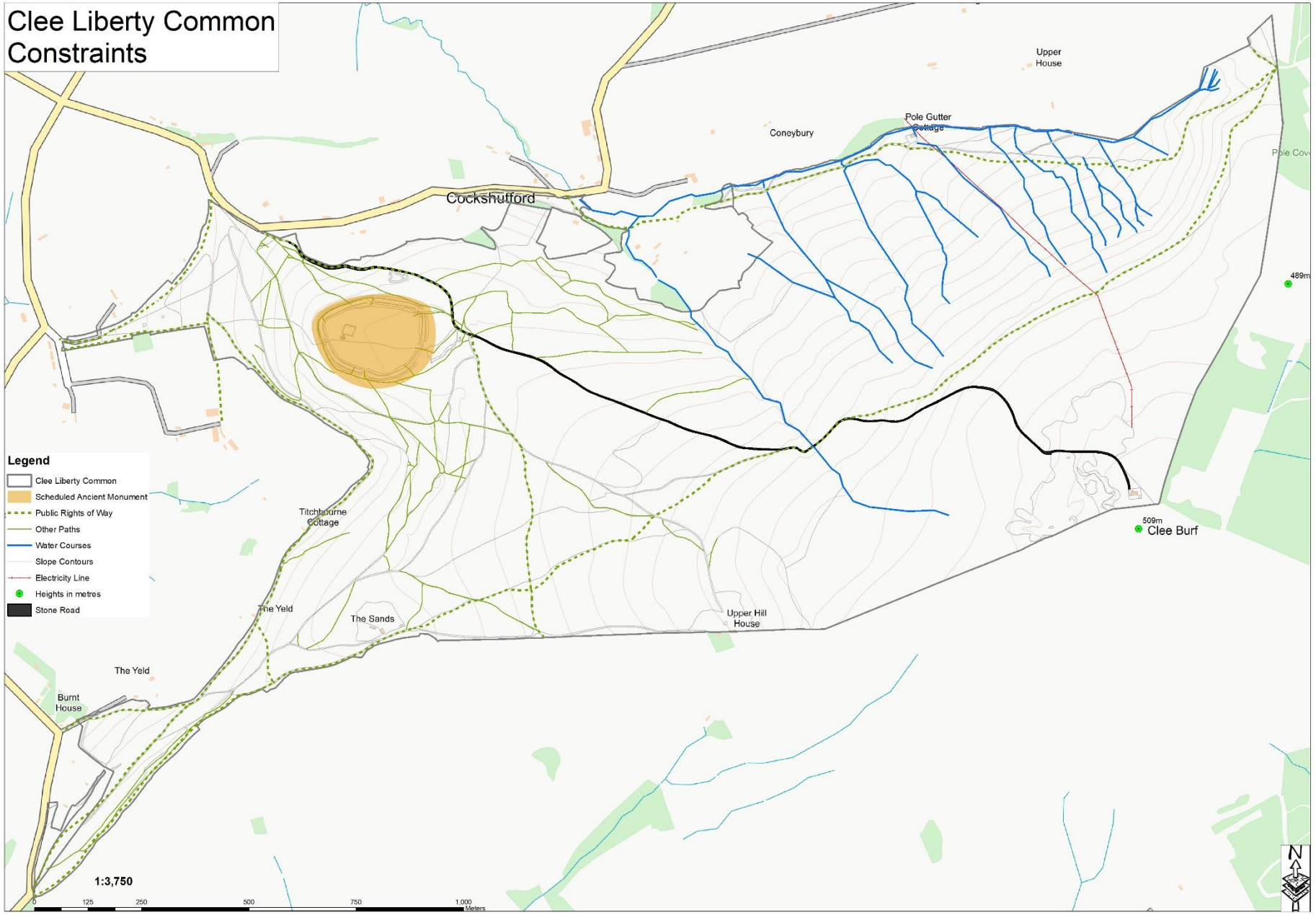


Figure 5. Slopes and gradients at Clee Liberty Common.

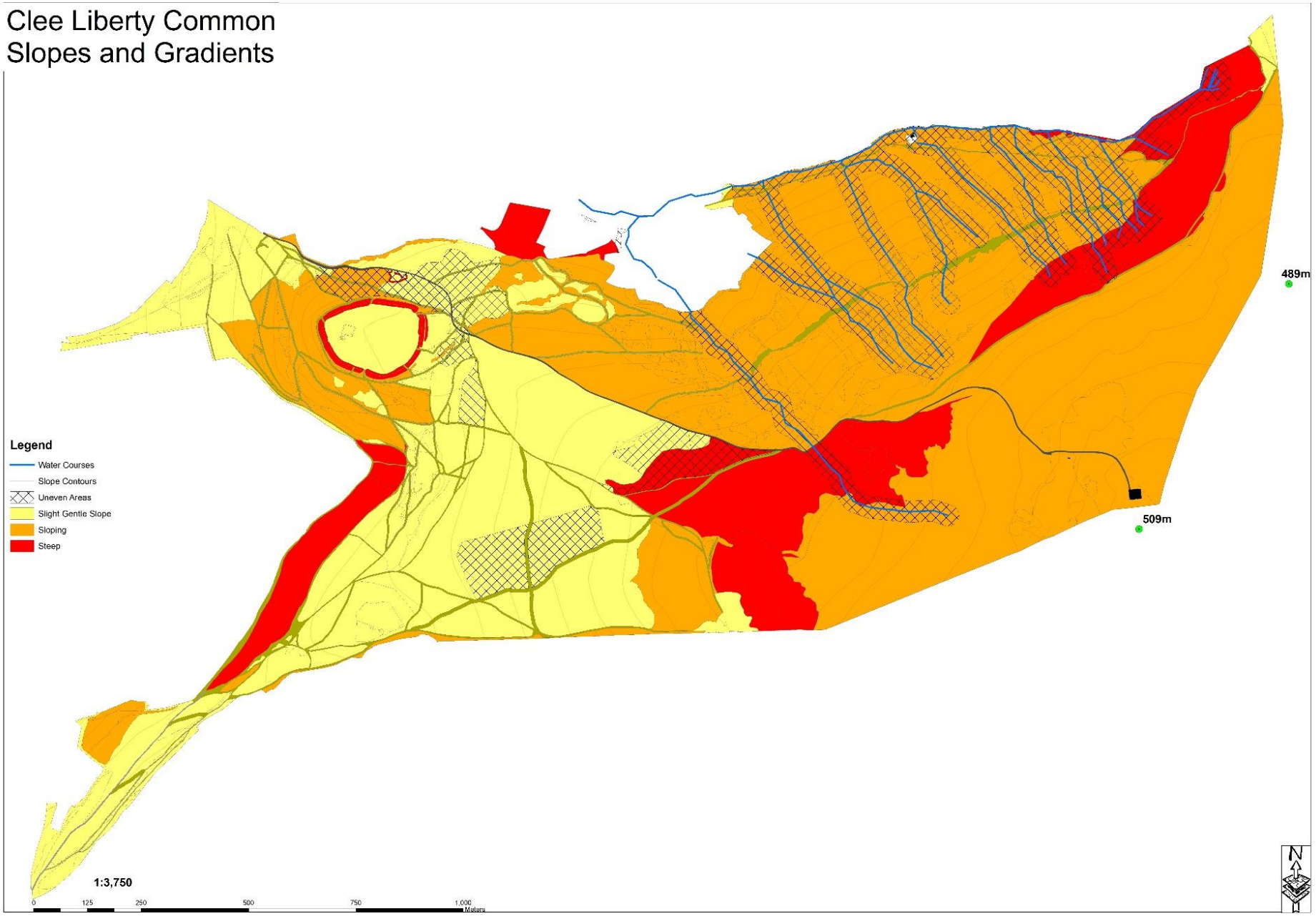
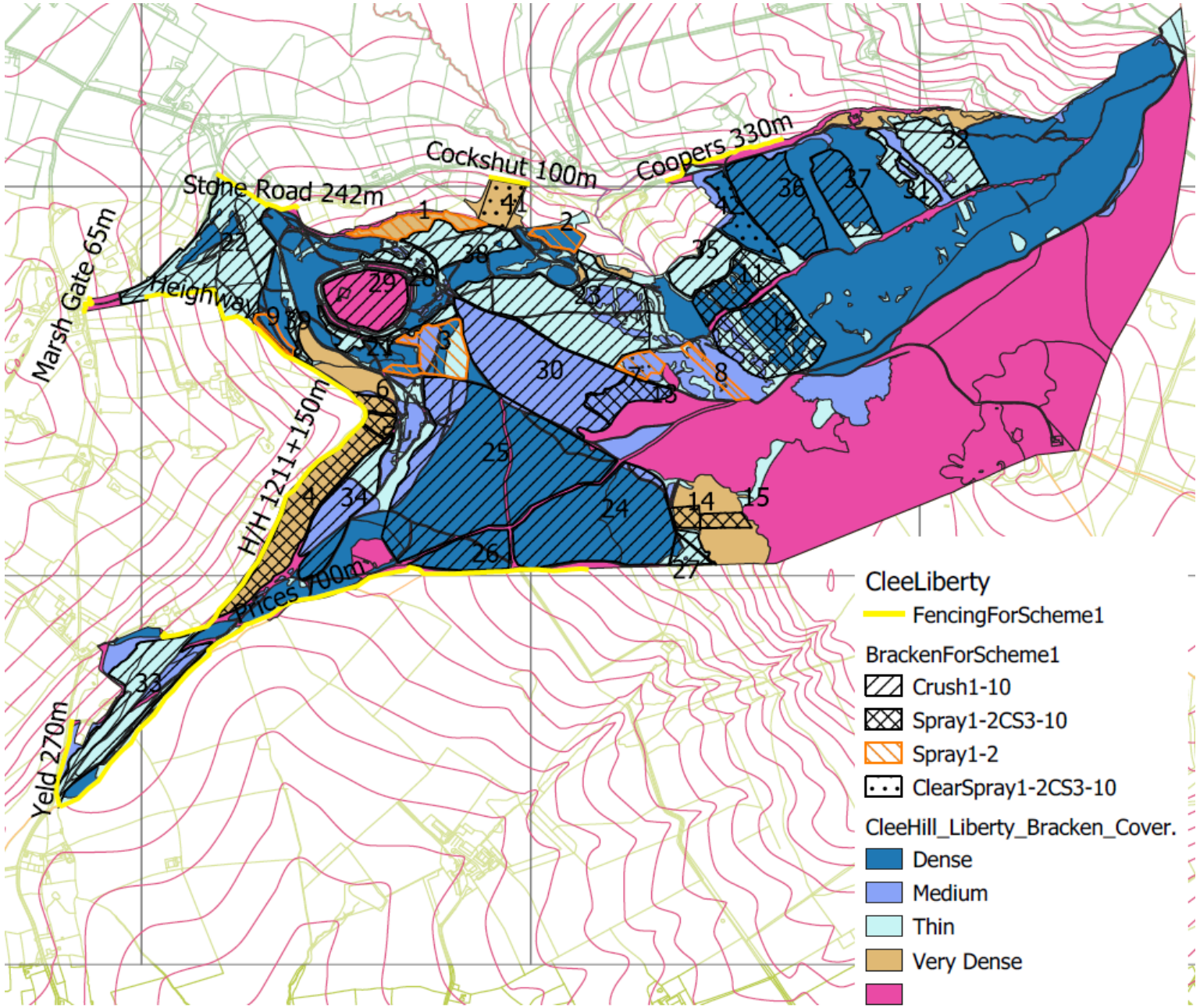


Figure 6. Aerial image of Clee Liberty Common from 2019.

Figure 7. Management under Higher Level Stewardship 2019 as proposed by current land managers.



Appendix 1. Photographs of Clee Liberty Common.

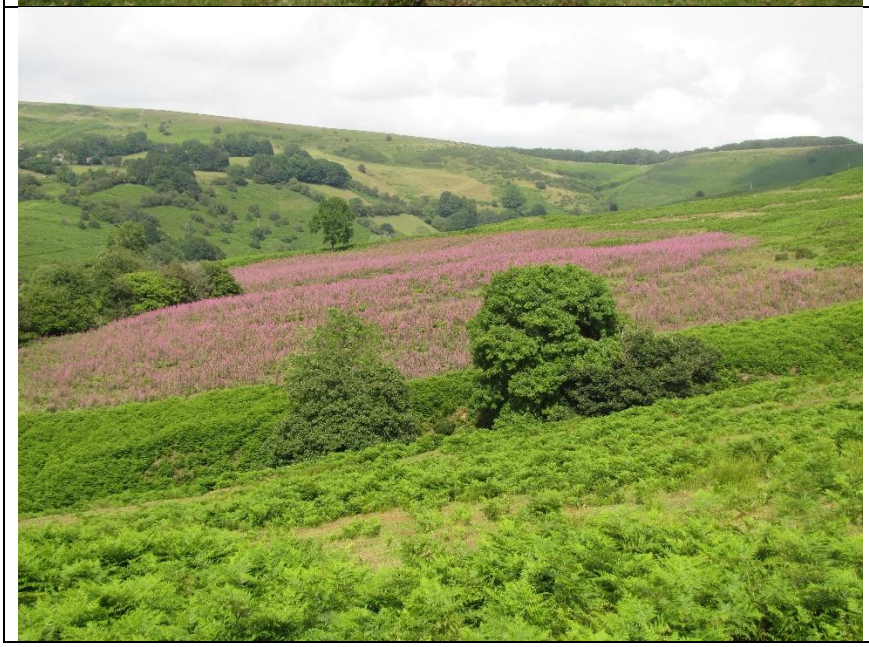
	From Nordy bank toward the Yeld April 2019.
	As above.
	Heath bedstraw. July 2019.

	From Five Springs to Cockshut April 2019
	Regular sheep track April 2019.

	Feeding station April 2019.
	From the Yeld to Nordy Bank April 2019.

	Some areas of soil erosion present on steep slopes. July 2019.
	One of the gulleys at the north boundary of the site. July 2019.

	‘Thin’ bracken July 2019.
	‘Medium’ bracken July 2019.
	‘Dense’ bracken July 2019.

	An area which has been crushed regularly since 2008. Almost complete eradication of bracken. July 2019.
	An area which has been regularly treated for bracken which is now becoming colonised by western gorse. July 2019.
	An area of the common treated with glyphosate in 2016. July 2019.

Appendix 2. Bird species observed on Clee Liberty Common during 2019 study.

Mallard
Red-legged partridge
Common pheasant
Wood pigeon
Swift
Cuckoo
Curlew
Sparrow hawk
Buzzard
Green woodpecker
Great spotted woodpecker
Kestrel
Jay
Magpie
Jackdaw
Rook
Raven
Carrion crow
Dunnock
House sparrow
Meadow pipit
Grey wagtail
White wagtail
Chaffinch
Bullfinch
Linnet
Goldfinch
Yellowhammer
Willow tit
Blue tit
Great tit
Skylark
Barn swallow
Willow warbler
Chiff chaff
Long-tailed tit
Wren
Starling
Robin
Stonechat
Song thrush
Mistle thrush
Blackbird

Appendix 3. Flowering plants observed on Clee Liberty Common during 2019 study.

Acer campestre	Field maple

Acer pseudoplatanus	Sycamore
Achillea millefoilium	Common yarrow
Agrostis canina	Velvet bent
Agrostis capillaris	Common bent
Agrostis stolonifera	Creeping bent
Aira caryophyllea	Silver hairgrass
Aira praecox	Early hairgrass
Alnus glutinosa	Black alder
Anthoxanthum odoratum	Sweet vernal grass
Aphanes arvensis	Parsley piert
Bellis perennis	Common daisy
Betula pendula	Betula pendula
Blechnum spicant	Hard fern
Briza media	Quaking grass
Calluna vulagris	Heather
Campanula rotundifolia	Harebell
Cardamine pratensis	Cuckoo flower
Carex caryophyllea	Vernal sedge
Carex demissa	Common yellow sedge
Carex dioica	Dioecious sedge
Carex echinata	Star sedge
Carex flacca	Glaucous sedge
Carex nigra	Slender tufted-sedge
Carex panicea	Carnation sedge
Carlina vulgaris	Lesser tufted sedge
Cerastium fontanum	Common mouse-eared chickweed
Chrysosplenium alternifolium	Alternate leaved golden saxifrage
Chrysosplenium oppositifolium	Opposite leaved golden saxifrage
Cirsium arvense	Creeping thistle
Cirsium palustris	Marsh thistle
Cirsium vulgare	Spear thistle
Crataegus monogyna	Common hawthorn
Cynosurus cristatus	Crested dogs-tail
Dactylis glomerata	Cock's foot
Danthonia decumbens	Heath grass
Deschampsia caespitosa	Tufted hair grass
Deschampsia flexuosa	Wavy hair grass
Digitalis purpurea	Fox glove
Dryopteris affinis	Scaly male fern
Dryopteris dilitata	Broad buckler fern
Dryopteris filix mas	Male fern
Eleocharis palustris	Common spike rush
Endymion non-scripta	Common bluebell
Epilobium palustre	Marsh willowherb
Equisetum palustre	Marsh horsetail
Eriophorum angustifolium	Cottongrass
Eriophorum vaginatum	Hare's tail cottongrass
Euphrasia sp	Eyebright
Fagus sylvatica	European beech

Festuca ovina	Sheeps fescue
Festuca rubra	Red fescue
Fraxinus excelsior	European Ash
Galium palustre	Marsh bedstraw
Galium saxatile	Heath bedstraw
Geranium molle	Dove's-foot crane's-bill
Geranium robertianum	Herb robert
Glyceria declinata	Small sweet grass
Hieracium pilosella	Mouse-ear-hawkweed
Holcus lanatus	Yorkshire Fog
Holcus mollis	Creeping softgrass
Hypericum	
Hypericum tetrapterum	Square-stalked St John's-wort
Ilex aquifolium	Common holly
Juncus acutiflorus	Sharp-flowered rush
Juncus bufonius	Toad rush
Juncus conglomeratus	Compact rush
Juncus effusus	Soft rush
Juncus inflexus	Hard rush
Juncus squarrosus	Heath rush
Laburnum anagyroides	Laburnum
Lemna minor	Duckweed
lolium perenne	Perennial ryegrass
Lonicera periclymenum	Common honeysuckle
Lotus corniculatus	Bird's-foot trefoil
Lotus pedunculatus	Greater Bird's-foot-trefoil
Luzula campestris	Field wood-rush
Luzula multiflora	Common wood-rush
Lysimachia nemorum	Yellow pimpernell
Lythrum portula	Spatulaleaf loosestrife
Medicago lupulina	Black medic
Mentha aquatica	Water mint
Moilinia caerulea	Purple moor-grass
Myosotis ramossissma	Early forget-me-not
Myosotis secunda	Creeping forget-me-not
Nardus stricta	Mat grass
Nasturtium	
Oreopteris limbosperma	Lemon-scented fern
Oxalis acetosella	Wood sorrel
Pedicularis sylvatica	Small lousewort
Plantago lanceolata	Ribwort plantain
Plantago major	Broadleaf plantain
Poa annua	Annual meadow grass
Polygala serpyllifolia	Heath milkwort
Potamogeton polygonifolius	Bog pondweed
Potentilla anserina	Silverweed
Potentilla erecta	Tormentil
Potentilla sterilis	Barren strawberry
Prunella vulgaris	Self-heal

Prunus spinosa	Blackthorn
Pteridium aquilinum	Eagle fern
Quercus petraea	Sessile oak
Ranunculus acris	Meadow buttercup
Ranunculus ficaria	Lesser celandine
Ranunculus flammula	Lesser spearwort
Ranunculus hederaceus	Ivy leaved crowfoot
Ranunculus repens	Creeping buttercup
Rosa canina	Dog rose
Rubus fruticosus	Bramble
Rumex acetosa	Common sorrel
Rumex acetosella	Sheep's sorrel
Rumex conglomeratus	Clustered dock
Rumex obtusifolius	Broad-leaved dock
Sagina procumbens	Pearlwort
Salix cinerea	Grey willow
Sambucus nigra	Elder
Scutellaria minor	Lesser skullcap
Senecio jacobaea	Stinking willie
Silene dioica	Red campion
Sorbus aucuparia	Rowan
Stellaria alsine	Bog stitchwort
Stellaria graminea	Starwort
Stellaria media	Chickweed
Taraxacum officinale	Common dandelion
Teucrium scorodonia	Woodland germander
Thymus polytrichus	Wild thyme
Triflium repens	White clover
Ulex gallii	Western gorse
Ulex minor	Common gorse
Urtica dioica	Common nettle
Vaccinium myrtillus	Bilberry
Valeriana dioica	Marsh valerian
Valeriana officinalis	Valerian
Veronica arvensis	Corn speedwell
Veronica chamaedrys	Germander speedwell
Veronica officinalis	Heath speedwell
Viola palustris	Marsh violet
Viola riviniana	Dog violet